Proceedings of Seventh International Symposium on Project Approaches in Engineering Education

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PAEE 2015

INTERNATIONAL SYMPOSIUM ON PROJECT APPROACHES IN ENGINEERING EDUCATION

INTERNATIONAL JOINT CONFERENCE
ON THE LEARNER IN ENGINEERING EDUCATION

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Proceedings of the Seventh International Symposium on Project Approaches in Engineering Education (PAEE'2015), integrated in the International Joint Conference on the Learner in Engineering Education (IJCLEE'2015)

Mondragon University
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International Joint Conference on the Learner in Engineering Education (IJCLEE'2015) was organized by Mondragon University, in collaboration with Active Learning in Engineering Education Workshop (ALE), International Symposium on Project Approaches in Engineering Education (PAEE) and International Research Symposium on Problem Based Learning (IRSPBL).

This is a digital edition.

Welcome to IJCLEE'2015

Imagination and initiative, which are catalytic elements for the learning process, are often constrained by classical tests. A manager of Velatia, a leading company of the energy sector, recently said to a group of students that they should be both curious and capable to find their own personal development path. The inherent curiosity, imagination and initiative of young people have to be directed through new educational methods. These methods should encourage a central role for the student in their learning process, taken profit of each mistake as an opportunity to foster both learning and personal growth. Active learning methods, such as problem and project based learning methods (PBL), acceptance is increasing at all levels of the educational community; from primary school to university. A PBL student faces a challenging problem which must be solved where imagination and initiative are essential to solve the problem.

We need to remind that our society is facing new dramatic global challenges, never seen before in human history, due to resource scarcity or environmental pollution among others. These new global challenges require new global tools to be confronted, tools such as the worldwide internet network. These new tools generate huge amounts of knowledge, which are increasingly more difficult to handle. In order to manage the vast amount of available knowledge, as mentioned by Steve Coll, future professionals will be forced to build their career by catalyzing thinking and self-learning in a sustainable way over a long period. A higher-level of thinking will be needed and students should be trained to fast and efficiently adapt to new scenarios and build the required new mental structures. PBL strategies provide an invaluable opportunity to achieve these higher-level of thinking.

Over the last 15 years, Mondragon University (MU) has been adapting its educational practice by giving more room to active learning methods. Nowadays, an interdisciplinary PBL approach is put into practice in all the studies offered by MU. By organizing the Joint Conference on the Learner in Engineering Education (IJCLEE 2015), our aim is to take our commitment to active methods one step further and to exchange experiences with universities around the globe.

We would like to express our sincere gratitude to the Active Learning in Engineering Education Network (ALE), the International Symposium on Project Approaches in Engineering Education (PAEE) and the International Research Symposium on Problem Based Learning (IRSPBL) for their collaboration and for giving us the opportunity to host the IJCLEE 2015.

We hope you will enjoy the conference and your stay in San Sebastian.

Welcome to IJCLEE'2015

Nestor Arana-Arexolaleiba, chair IJCLEE 2015

Welcome to PAEE'2015

Dear Participants,

Welcome to the 7th International Symposium on Project Approaches in Engineering Education. This year is a special edition of the symposium as we have joined forces together with IRSPBL (International Research Symposium on Problem Based Learning) and ALE (International Research Symposium on Problem Based Learning) to create opportunities for cross fertilization and extensive networking of Engineering Education professionals who are dedicated to all kinds of active learning. We are happy to present an interactive programme that combines a variety of workshops, 11 paper sessions in English, Portuguese and Spanish, a poster session and a debate session. Interdisciplinarity, sustainability, business participation in projects, work study combinations and design learning are just a few of the topics that are to be discussed in paper and debate sessions.

The Department of Production and Systems of the University of Minho, the Curriculum Development Working Group of the European Society for Engineering Education (SEFI), and the Ibero-American Association of Institutes of Engineering Education (ASIBEI) aim to join teachers, researchers on Engineering Education, deans, students of Engineering Schools and professionals concerned with Engineering Education, to enhance active learning approaches in Engineering Education through workshops and discussion of current practice and research. We would like to thank the University of Mondragon for hosting PAEE as part of the joint conference.

On behalf of the PAEE2015 organising committee,

NATASCHA VAN HATTUM-JANSSEN

RUI M. LIMA

DINIS CARVALHO

ASIBEI Welcome Note

Palabras de Bienvenida PAEE'2015 por parte de ASIBEI,

El tema que se desarrollará este año en la reunión PAEE'2015 "International Joint Conference on the Learner in Engineering Education (IJCLEE 2015), en la pintoresca ciudad de Donostia – San Sebastián del 6 al 9 de julio, es una excelente oportunidad para sensibilizar a la comunidad académica sobre las brechas que existen entre las necesidades de la sociedad, y los procesos curriculares que se imparten en las universidades e instituciones de educación superior. Las características que deben procurarse en los ingenieros incluyen el carácter general y la amplitud de la base de los conocimientos; la destreza para aprender y el compromiso con el aprendizaje continuo; la competencia para resolver problemas de diseño de soluciones abiertas y de enfoque multidisciplinario; el liderazgo y la habilidad de comunicación, incluyendo una segunda lengua; la competencia en las áreas de administración, finanzas y economía; la habilidad para integrarse con eficacia en equipos de diseño; la comprensión de la interacción entre ingeniería, desarrollo y sociedad; la fundamentación ética y el aprecio por los valores, la cultura y el arte; y la capacidad de utilizar el creciente poder de las telecomunicaciones y las herramientas informáticas.

La Asociación Iberoamericana de Instituciones de Enseñanza de la Ingeniería –**ASIBEI**- ha seguido manteniendo una alianza estratégica con PAEE (Project Approaches in Engineering Education) convencidos que estas sinergias son importantes para el presente y futuro desarrollo de nuestros países. Por lo tanto, todo esfuerzo que se haga en esa dirección, será fundamental para alcanzar el bienestar de nuestras sociedades, ya que ellas requieren de una ingeniería suficientemente robusta para procurar unas mejores y dignas condiciones de vida. Un ejercicio profesional que satisfaga esas expectativas debe estar construido sobre una política clara de formación de profesores responsable y sostenida, un conjunto de componentes curriculares,tales como, el aprendizaje basado en proyectos de interés social, aprendizaje activo y demás estrategias de enseñanza aprendizaje, pasando por la responsabilidad de las instituciones de educación en ingeniería, que orienten a los estudiantes en la fundamentación científica – tecnológica- social, en el diálogo con sus pares en el mundo y en el desarrollo de habilidades para ofrecer alternativas plausibles de solución que permitan enfrentar exitosamente los problemas reales de la sociedad.

ASIBEI augura los mejores éxitos en el cumplimiento de los objetivos propuestos.

Con aprecio,

JAIME SALAZAR CONTRERAS

Secretario Ejecutivo ASIBEI (www.asibei.net)

Junio de 2015

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IJCLEE'2015 Invited Speakers

IJCLEE/PAEE'2015 attracted renowned keynote speakers, who are experts at Engineering Education in general and Project Approaches in particular. We are honoured to have the following inspiring keynote speakers in the IJCLEE'2015:

- Dr. Erik de Graaff - UNESCO Centre In Problem Based Learning - Aalborg University - Denmark
- Dr. Jennifer Turns - Department of Human Centered Design & Engineering - University of Washington, USA
- Dr. Michael Christie - Faculty of Science, Health, Education and Engineering - University of the Sunshine Coast - Australia
- Dr. Vincent P. Manno - Provost and Dean of Faculty - Olin College of Engineering in Needham, MA, USA
- Ms. Virginie Servant - Education Psychology - Erasmus University – Netherlands

Virginie Servant

Theme: Three Intellectual Disputes that shaped PBL – A Historical Account

This talk will explore the intellectual history of Problem-based learning through the three historic "battles" that shaped the way this method is applied across disciplines and countries. This talks begins with an overview of the philosophical and intellectual influences on the different models of PBL. The presentation will then take the audience back to the early 20th Century and the first of the three intellectual disputes – Dewey v. Kilpatrick, which could also be coined "Problems v. Projects". Then, fast-forward to the 1960s, and the second educational dispute between the behaviourists and the humanists, exemplified with regards to PBL in Rogers v. Mager. The final dispute takes us to the 1980s, and pits Popperians against the General Problem Solvers – this dispute is exemplified by the disagreement between Schmidt and Barrows. Through pictures, historical documents, archive materials, oral history quotes and extracts from contemporary publications, the audience will be able to engage with the history of PBL and understand where the differences in application stem from.

Short bio

Virginie Servant specializes in the study of the history, philosophy and practice of problem-based learning, from its roots in Canada, Denmark and the Netherlands to its modern expansion in Asia. Methodologically, Ginie is a qualitative researcher, versed in diverse qualitative methods such as Interpretive Phenomenological Analysis, Oral History, and Focus Group Interviews.She is now studying a PhD in Education Psychology at Erasmus University (Netherlands).

Under the supervision of Professor Henk Schmidt, which is scheduled for completion in September 2015. After a working on higher education teaching & learning and Ed Tech research with the Singapore-based institute "The HEAD Foundation" for two years, she founded Promethea Education, a higher education educational research and consultancy organization. She conducted in-depth research into problem-based pedagogy in Asian universities. This research led to the "PBL in Asia series", the first comprehensive Pan-Asian overview of PBL.

Alex Tarchini

Theme: The Impact of Model Based Design

Model-Based Design has dramatically expanded to change how today's smarter systems are developed. Driven by the product-development needs of industry, Model-Based Design has grown to encompass system analysis and algorithm design, implementation through automatic code generation, plus verification and validation on both models and embedded code. Today, Model-Based Design is used in every industry that leverages control systems, including aerospace, automotive, industrial automation, medical devices, robotics, and energy. It is used not only for control systems but also for multidisciplinary systems that incorporate controls, computer vision, signal processing, communication, and other functionalities. Model-Based Design is evolving to help researchers and developers looking at the challenges of cyber-physical systems, distributed systems, and other systems of the future.

Xavier Fouger

Theme: Digital technologies, a language for problem solving

In industry, digital technologies are becoming the language of problem solving, providing a platform to express, share, validate, experience and implement solutions in a socio-technical context. In education, they favour peer learning in multicultural, dispersed groups of students and they provide a realistic learning context reflecting rapidly evolving industry methods. As social engineering practices and the Internet of Things emerge as promising industry trends taking benefit of digital technologies and reshaping the behaviours of engineers, Engineering Education makes its first experiences in those domains. The presentation goes through a series of examples and extracts lessons from learning projects across the globe.

Vincent P. Manno

Theme: The Critical Role of Active Learning in Rebalancing Foundational Engineering Education

An engineering student's *foundational* educational experience not only affects her or his learning outcomes and career but also whether or not that student decided to consider engineering education in the first place. While passive knowledge acquisition and assimilation can be effective for a fraction of learners, exclusive utilization of such approaches is self-limiting. It is somewhat disturbing to note that this realization long predates the current focus on improving 21st Century engineering education. Washington Roebling, the chief engineer of the Brooklyn Bridge, reflecting on his education in the 19th Century and its disconnection with the challenges of an actual engineering project wrote 'that the terrible treadmill of forcing an avalanche of figures and facts into young brains not qualified to assimilate them...I am still busy trying to forget the heterogeneous mass of unusable knowledge that I could only memorize...'

Education in all fields but engineering in particular being rooted in application need to include substantial active learning components. Foundational engineering education should provide a balance of experiences that prepare students to synthesize and utilize knowledge so that they can conceive creative design solutions that address more than feasibility. Students need to *practice* at being engineers; process needs to takes precedence over content. Achieving this rebalancing will not be easy given the existing discipline-centric structure of most undergraduate programs and the over-dominance of research and theory over practice in these initial educational experiences. The goal of this talk is to stimulate discussion about how to create pedagogical constructs that embed effective active learning throughout an engineering educational program. The talk will include examples and lesson learned from the Olin College of Engineering, among them the critical impact of culture and the need to alter the roles of students and faculty.

Short bio

Vincent P. Manno is Provost and Dean of Faculty, as well as Professor of Engineering, at the Olin College of Engineering in Needham, MA. He received a BS from Columbia University and MS, Engineer's and Doctor of Science degrees from M.I.T. His fields of interest are power generation, electronics thermal energy management, manufacturing processes, as well as engineering education policy. He has authored or co-authored over 150 journal articles, conference proceeding papers and technical reports and holds a US patent. Prior to joining Olinin 2011, Dr. Manno was Associate Provost and Professor of Mechanical Engineering at Tufts University. He has worked in the private sector and served as a U.S. Navy Senior Summer Faculty Fellow. He is a Fellow of the American Society of Mechanical Engineers (ASME) and the recipient of Ralph R. Teetor Educational Award, the Harvey Rosten Award for Excellence in the Thermal Analysis of Electronic Equipment, the ASME Curriculum Innovation Award, the Fischer Award as Tufts Engineering Teacher of the Year, and the Tufts University Seymour Simches Award for Distinguished Teaching and Advising. He currently serves on the advisory boards of Ashesi University (Ghana), the University of Delaware College of Engineering and the Tufts University Center for Engineering Education Outreach.

Dr. Michael Christie and Dr. Erik de Graaf

Theme: An essay on the Active Learner in Engineering Education

We know from researchers like Hounsell, Entwhistle, Marton, and Biggs [2005 & 1999] that students will approach their learning differently depending on the pedagogical models that their lecturers use. Lecturers can encourage students to take a surface or passive approach to their learning if they enter into an unholy alliance with their students by telling them to study for the test, by giving them hints on what will be in the test during lectures, and by testing for declarative knowledge. They can encourage a deep or active approach to learning if they require their students to apply their knowledge and skills in real world situations and if they use continuous, authentic assessment tasks that test for understanding and application of the subject. This is the third keynote in a series designed by the authors for ALE conferences. In the first, in Copenhagen, Denmark, in 2012, they endeavoured to build a philosophical basis for ALE by reference to John Dewey's 'progressive' approach to education. They stressed at that time that there are good and bad aspects in the practical application of both traditional and progressive pedagogical models. In the second keynote at Caixos du Sol, Brazil, in early 2014, they focussed on the sort of questions active engineering educators would ask if they wish to engage in the scholarship of teaching and learning. In this 2015 interactive keynote session they will have participants define what they think active learning means by asking them to give examples of how they themselves have implemented active learning in their own teaching. Based on these examples (and those taken from past ALE conferences) they will summarise the key factors in Active Learning in Engineering Education and seek consensus on a common meaning for the term which is at the very heart of ALE.

Short bio

From 1999 to 2012 Michael Christie worked in Sweden, first at Chalmers University of Technology in Gothenburg, where he was in charge of a teaching and learning centre, and then from 2010 at Stockholm University, where he was Sweden's first Professor of Higher Education. During that time he has been an active member of ALE and served on the advisory committee. Michael's research is concerned with fundamental epistemological questions such as how knowledge is built and the best ways of promoting learning in engineering and higher education. He is also interested in the most pedagogical ways of using digital tools in teaching and learning. Having run courses for PhD supervisors as well as supervising and marking PhD theses, he is currently researching the most efficacious way of supporting the PhD process. His own PhD was a contact history between Aborigines and Colonists in early Victoria, 1836-1886, and he has maintained an interest in cross-cultural research. In Sweden he received substantial funding for research and development projects aimed at improving learning and teaching in Higher Education. He took up his current post at the University of the Sunshine Coast in February 2013.

Erik de Graaff is trained as psychologist and holds a PhD in social sciences. He has been working with Problem Based learning (PBL) in Maastricht from 1979 till 1980. In 1994 he was appointed as associate professor in the field of educational innovation at the Faculty of Technology Policy and Management of Delft University of Technology. Dr. de Graaff has been a visiting professor at the University of Newcastle, Australia in 1995 and a guest professor at Aalborg University in Denmark. The collaboration with Aalborg University led to an appointment as full professor at the department of Development and Planning in 2011. Dr. de Graaff is recognized as an international expert on PBL. He contributed to the promotion of knowledge and understanding of higher engineering education with numerous publications and through participation in professional organizations like SEFI, IFEES and ALE. He has published over 200 articles and papers and he has presented more than 70 keynotes and invited lectures on various topics related to PBL in higher education, like Working with PBL, Management of change, Assessment and evaluation, Methods of applied research and Collaboration between university and industry. Since January 2008 he is Editor-in-Chief of the European Journal of Engineering Education.

Dr. Jennifer Turns

Theme: Reflection: Understanding, Enabling, and Appreciating

In order to improve engineering education, educators in engineering are adopting teaching methods such as problem-based learning, active learning, and experiential learning. To realize the potential of such approaches, educators must implement features that make them effective. In this talk, I will focus one such feature: student reflection.

Reflection is a form of thinking in which one explores the meaning of experiences and the consequences of the meaning for future action. Engaging in reflection can benefit students in many ways, including improved learning, motivation, and persistence. Despite the importance of reflection as a component of learning by doing, Susan Ambrose[1], an internationally recognized expert in teaching and learning, has noted, "…students learn by doing, but only when they have time to *reflect*—the two go hand in hand. Why, then, don't engineering curricula provide constant structured opportunities and time to ensure that continual *reflection* takes place."

Limited emphasis on reflection may arise because reflection can be hard to understand, difficult to enable, and subsequently challenging to appreciate. In this talk, I will describe research and practice efforts that speak to these three issues—understanding, enabling, and appreciating. I will talk about two research-through-design activities and address the question: what lessons related to understanding, enabling, and appreciating student reflection arose through efforts to support reflective essay writing and professional portfolio creation? I will also talk about how these lessons informed a current project: The Consortium to Promote Reflection in Engineering Education. In this part of the talk, I will address the question: What is entailed in (and being learned from) creating a large-scale, multi-campus sustained focus on reflection?

Short bio

Jennifer Turns is a professor in the Department of Human Centered Design & Engineering at the University of Washington. She is also a faculty affiliate with the UW Center for Engineering Learning and Teaching. Dr. Turns received her Ph.D. in Industrial Engineering from the Georgia Institute of Technology, her M.S. in Systems Engineering from the University of Virginia, and her B.S. in Systems Engineering from the University of Virginia. Dr. Turns' research interests lie at the intersection of engineering education, cognitive/learning sciences, and user-centered design. Her engineering education work has focused on engineering design learning, knowledge integration, and disciplinary understanding, and has involved the use of a wide variety of research methods including verbal protocol analysis, concept mapping, and ethnography. Turns' ground-breaking research makes her one of the most highly-respected specialists in the engineering education field.

[1] Ambrose, S. A. (2013). Undergraduate engineering curriculum: The ultimate design challenge. The Bridge: Linking Engineering and Society, 43(2).

PAEE'2015 Programme

IJCLEE week programme

6 Mon	7 Tue	8 Wed	9 Thu	10 Fri
ALE Workshop	PAEE Symposium	Joint Keynote Speakers	IRSPBL Symposium	Post conference workshops
	Gala dinner option			

PAEE day programme

	PAEE - 07/07/2015	
Hour	**Session**	**Room**
08:00	Registration	2nd floor hall
09:00	PAEE - Welcome and instructions	Plenary Room
09:30	PAEE - Workshop 1 - Designing Teaming Experiences: Research and Practice	F111
	PAEE - Paper Session 1A (en)	F104
	PAEE - Paper Session 1B (en)	F107
	PAEE - Paper Session 1C (pt)	F109
	PAEE - Paper Session 1D (sp)	F110
11:00	Refreshments	
11:30	PAEE - Workshop 2 - MathWorks - Why creating ALGORITHMS will be the 'new literacy'	F111
	PAEE - Paper Session 2A (en)	F104
	PAEE - Paper Session 2B (en)	F107
	PAEE - Paper Session 2C (pt)	F109
	PAEE - Paper Session 2D (sp)	F110
13:00	Lunch	
14:00	PAEE - Workshop 3 - Unpacking the language of "Impact" and "Success" in PBL	F111
	PAEE - Poster Session	F106
15:30	Refreshments	
16:00	PAEE - Debate Session UBC - University Business Cooperation	F111
	PAEE - Paper Session 3A (en)	F104
	PAEE - Paper Session 3B (sp)	F110
	PAEE - Paper Session 3C (pt)	F109
17:30	PAEE - Close	
20:00	Gala dinner option	

PAEE'2015 Workshops

An important feature of the PAEE Symposium is the workshop programme. Projects approaches to learning are usually aimed at the increase of student involvement in learning, therefore, a symposium on project approaches like PAEE'2015 count on active involvement of its participants. Three different workshops are scheduled, meant to enable the enhancement of project practice and the reflection on practice.

Workshop 1 - A Student-Centered Approach to Designing Teaming Experiences: Research and Practice

Lynn Andrea Stein, Jessica Townsend, Mark Somerville, Debbie Chachra - Olin College of Engineering, Needham, MA, USA

We often approach teaming in course design with a very simple philosophy: If students are put on teams, they will learn teamwork skills and get the educational benefits of teaming. In reality, team dynamics are complex and course design influences which of the plausible benefits of teaming students actually obtain. In this workshop, we explore the design of teaming experiences from a pragmatic perspective. Participants experience first-hand some of the complexities of team dynamics in project-based learning; consider how instructor choices in course design enhance or diminish the effectiveness of teaming; learn about some of the relevant background research; and begin to situate their own curricular choices within a framework for scaffolding successful teaming experiences. Participants employ design thinking tools (student personas, interaction narratives) in order to explore what a team, and the individual students team members, might experience within a given teaming paradigm. We identify team pitfalls, share a broader set of insights about student engineering teams, and discuss specific approaches to scaffolding the development of teaming skills that responds specifically to the needs of particular students and particular institutions.

Workshop 2 - Why creating ALGORITHMS will be the 'new literacy'

Alex Tarchini - MathWorks

Recently, there have been provocative articles asserting that coding is the "new literacy" but coding, like writing, is a mechanical act happening through an upgraded input/output and storage medium. Writing "if" statements and "for" loops is straightforward to teach people, but it does not make them any more capable. Despite the fact that the entire world is learning to code, coding without the ability to understand and express the characteristics of a complex system, will not help students to realize what is plausible for a computer system to fulfill and what are the trade-offs to accept when reality meets the digital world. Also, many are the challenges of manual coding, especially if the goal isn't simply to implement something, but rather to figure out the RIGHT, CONSISTENT, OPTIMAL design. Creating algorithms that model and control systems and simulating them is what we consider a better definition of "new literacy". It is also an activity with desirable side effects, as in order to represent a system, we have to understand what it is exactly and the more we understand it, the better we can model it so triggering a sort of virtuous hermeneutical circle. In addition, performing algorithm design in a computer-assisted environment, brings substantial added value in terms of additional services such as automation of repetitive operations or help in the evaluation of design alternatives. Let's explore together a few examples of how the modern literacy of algorithm design is finding its way in contemporary engineering education.

Workshop 3 – Unpacking the language of "Impact" and "Success" in Project-Based Learning Initiatives

Mel Chua[*], Lynn Andrea Stein[#] and Robin S. Adams[*] - [*] Purdue University School of Engineering Education, USA - [#] Franklin W. Olin College of Engineering, USA

Project-based learning (PBL) requires instructors to reexamine their perspectives on teaching. What counts as "success"? How should a course "impact" students, the institution, and the world? What language and practices do we use to describe and discuss these topics? In this workshop, facilitators will challenge participants to observe and disrupt their conversation patterns about "impact" and "success" in engineering education.

PAEE'2015 Paper Sessions, Debate Session and Poster Session

This program of sessions can be changed during the event. Please check the web version for updates.

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	193	Ciliana Regina Colombo, Francisco Moreira and Anabela C. Alves. Sustainability Education in PBL Education: the case study of IEM-UMINHO
	195	Lise B. Kofoed and Marian S. Stachowicz. Interdisciplinary Engineering and Science Educations – new challenges for master students
	207	Claes Fredriksson. Problem Based Teaching vs Problem Based Learning with CES EduPack
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	181	Jens Myrup Pedersen, Jose Manuel Gutierrez Lopez, Marite Kirikova, Lukasz Zabludowski and Jaume Comellas. Three years of an intensive Programme: Experiences, Observations and Learning Points
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	109	João Alberto Castelo Branco Oliveira, Gabriela Ribeiro Peixoto Rezende Pinto, Jéssica Magally de Jesus Santos. Uso de Estratégias Ativas na Educação em Engenharia no Brasil: um mapeamento sistemático de experiências a partir das publicações realizadas no COBENGE
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IJCLEE/PAEE’2015 Submissions

The Seventh International Symposium on Project Approaches in Engineering Education (PAEE’2015), integrated in the International Joint Conference on the Learner in Engineering Education (IJCLEE’2015) has three type of submissions in up to three languages (English, Portuguese and Spanish):

- **Workshop submissions**, aiming to encourage discussion of current practice and research on project approaches.
- **Full Papers** for paper sessions, including standard research submissions, papers of PBL experiences describing implementation issues. Any of these papers can be selected and presented in a Debate Session, in which a set of papers’ authors will be invited to discuss a common theme.
- **Poster submissions**, including submissions adequate for a poster presentation in an interactive model.

All full paper submissions were double reviewed by the PAEE 2015 scientific committee, and in same cases add a third review. After notification of acceptance authors were invited to submit a final paper of 6 to 8 pages long in Microsoft Word format, using the available PAEE template. Accepted contributions were invited to make a presentation at the symposium.

The proceedings are published under the Guidelines on Open Access to Scientific Publications and Research Data in Horizon 2020 (http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-pilot-guide_en.pdf): "Open access to scientific publications refers to free of charge online access for any user." The authors retain the copyright of their work.

Publication Ethics and Malpractice Statement

The International Symposium on Project Approaches in Engineering Education – PAEE, is being organized by the Department of Production and Systems Engineering, University of Minho, since 2009, aiming to join teachers, researchers on Engineering Education, deans of Engineering Schools and professionals concerned with Engineering Education, to enhance Project Approaches in Engineering Education through workshops and discussion of current practice and research.

The PAEE editorial board is committed to preventing publication malpractice, does not accept any kind of unethical behaviour, and does not tolerate any kind of plagiarism. Authors, editors, and reviewers of PAEE are to be committed with good practice of publications and accept to fulfil the duties and responsibilities as set by the COPE Code of Conduct (http://publicationethics.org/resources/code-conduct). Based on these, PAEE expects authors, editors and reviewers to be committed to the following general guidelines:

- Editors take decisions on the acceptance of papers, and compose and evaluate the proceedings quality.
- Ensure that all published papers have been fairly reviewed by suitably qualified reviewers.
- Expect original submissions from the authors, and discourage misconduct.
- Expect that authors are responsible for language quality.
- Expect that the authors adequately reference the sources of their work.
- Ensure confidentiality of submissions and reviews.
- Reviewers do a fair and detailed review of paper(s) assigned to them.

IJCLEE/PAEE'2015 List of Submissions

IJCLEE/PAEE'2015 Invited Speaker Communication

This section presents the communication written by two of the invited speakers of IJCLEE'2015: Dr. Erik de Graaff and Dr. Michael Christie.

An essay on the Active Learner in Engineering Education

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Text to accompany the keynote interactive session for the International Joint Conference on the Learner in Engineering Education (IJCLEE 2015)

Engineering and Medical Education have made significant contributions in the area of pedagogical modelling. In both cases the emphasis has been on the active learner in medical or engineering education. One could argue that it is tautological to use a term such as 'the active learner'. A person cannot learn unless the brain or body is active in some way or other. If learning is something we do which results in a discernible and fairly permanent change in what we know, or can do, or value, then a learner is by definition a doer, an active agent. From the moment we are born, and perhaps even in the womb, we are learning. Babies are practising scientists, experimenting, developing and testing hypotheses. 'If I cry loud enough will someone change my nappy? If I say mamma I get cuddles and smiles from everyone but especially from her'. It will take time before this natural instinct becomes a more conscious and reflective activity, before we think and learn in a more deliberate and problem solving way.

All of us, no matter what our age, naturally pursue new knowledge, skills, and values, or busily reinforce or revise what we already know, do and feel. John Dewey's timeless explanation of how we learn best by first doing and then reflecting on what we have done, was a starting point for our first ALE keynote in Copenhagen in 2012. At that conference we expanded on this theme and argued for a philosophical basis to ALE. Using Dewey we challenged an Engineering tradition that both of us have experienced. At Chalmers and Delft universities of technology we had experienced an unholy alliance between teachers and students. Higher Education is still characterised by written tests of students' knowledge and skills and by sorting those students into graded categories. In such a system getting the best grade, or just getting through, depending on your educational ambitions, is what motivates students. In such a system political, economic or other pressures can lead some teachers and students to agree on an unwritten pact. The teachers, who really want to be researchers (since that is where the academic rewards are) say, in effect: 'I'll provide heavy hints to what will be in the closed-book, end-of-term exam in my lectures. Go through my old exam papers and make sure you can answer the questions there. I don't have time to hand-feed you'. The questions that such lecturers set often test declarative knowledge and set ways of applying that knowledge. The students who want to simply get their meal ticket are content. The students who really want to deeply understand and apply the subject in new and different situations are frustrated. The Swedish expression for this is 'korvstoppning', which translated literally means 'stuffing the sausage'. The English call it 'cramming'. The teachers who push this approach reinforce their distaste for teaching but also free up time for research. They can publish more and unfortunately reap the rewards of a system that privileges research over teaching. Unfortunately in this educational approach the students become passive recipients of knowledge. The teacher is seen as the one who supplies content. All they need to do is learn it off by heart and repeat it in the end of course exams.

At Caxias do Sul in early 2014 we expanded on our argument for the importance of activating learning. We stressed again that we are all natural scientists and encouraged participants at our interactive keynote to devise and critique relevant research questions in their scholarly investigation of how to best encourage and implement active learning in Engineering Education. This year we concentrate on the theme of 'the Active

Learner in Engineering Education', a theme that binds the PBL Symposium, the ALE Workshop and the Project Approach to Engineering Education Conference together. It is a fitting focus for what is a ground-breaking event in Engineering Education.

We described above how students can be put in fairly passive position when it comes to learning. We know from researchers like Hounsell, Entwhistle, Marton, and Biggs [1] that students will approach their learning differently depending on the pedagogical models that their lecturers use. We want to stress from the outset that although we favour a what Dewey's calls a 'progressive' approach to education there are good and bad aspects in the practical application of both traditional and progressive models. Teachers in both approaches have a great deal of responsibility. They can influence students to take what the literature refers to as a surface approach to learning. If the lecturer tests mainly for declarative knowledge students can get away with not truly understanding and applying what they are taught. It takes skill for a teacher to design a course so that students are required to take a deep approach, in other words, to really understand the subject matter and prove that by applying it in new and different situations. Models such as Problem and Project Based Learning consciously strive to activate students and a well designed PBL course has inbuilt in it authentic assessment tasks.

Dewey used the word 'Progressive' to contrast his educational approach to the 'Traditional' model that he saw in contemporary American schooling in the early 1900s. The shortcomings in either model are most obvious when practitioners pervert the philosophical and pedagogical reasons for employing one or other of the models. Some disciplines, like Medicine and Engineering, have a large amount of content and technical language that must be learned in order to communicate key concepts or carry out correct procedures. For example you must know anatomical terms if you are going to discuss and diagnose a disorder or deal with a problem in a particular part of the body. The same is true for engineers who must know formulas and technical terms if they are going to design, build and test a product or determine the causes of problems with a product. The medical student who rote learns the Latin names for parts of the body is an active learner. The engineering student who remembers formulas by heart is also an active learner. The student debating in her mind the content of a lecture she is listening to is also actively learning. But if this is all the student does then we are short changing them. Social engagement with and the practical application of knowledge, skills and values are necessary to truly activate what has been learned as an individual, no matter what educational model is used.

Lecturers who love their subject and want to inspire others to learn about it tend to activate their learners even when they teach in a university that is still very traditional in terms of its values and educational architecture. However it is much easier to do that when one is working in a university like Aalborg, Denmark, that was purpose built to deliver PBL curricula. Inspiring teachers, even if they are locked into a format of lecture, tutorial, laboratory exercises and final, closed-book exam, can still devise ways of helping students to really understand and apply the content of their course. However it is easier to do that if the model has been constructed to promote understanding and application. Most of you here today fit the category of 'inspirational teacher'. The proceedings from earlier conferences, workshops and symposia are proof of the amazing creativity and versatility you use to activate your learners. The interactive part of this keynote will allow you to share some of those ideas, techniques, exercises and systems.

Engineering, Medicine and Economics are rather conservative disciplines so it comes as a surprise that progressive educators in these disciplines have been energetic advocates for two of the most influential pedagogical models to have emerged in Higher Education in the last half century. We refer to Problem Based and Project Based Learning (PBL). In essence these two pedagogical models have been around for thousands of years. Both Confucius and Socrates (c 500 and 400 BC) stimulated rather than transmitted learning. Socrates is famous for his dialogues that forced students to think, question and problem solve. Confucius knew the importance of intrinsic motivation and commented: 'I only instruct the eager and enlighten the fervent. If I hold up one corner and a student cannot come back to me with the other three, I do not go on with the lesson'. One of the earliest and best known varieties of PBL is the form that was introduced in the Faculty of Health Sciences at McMaster, a Canadian University, in 1969. It was soon adopted elsewhere including at the medical faculties of the University of Limburg in Maastricht, Holland, the University of Newcastle, Australia, and the University of New Mexico in the United States. Today it is a worldwide phenomenon.

As is too often the case, 'followers' of a new educational model can became more dogmatic about its practice than the founders [2]. In 1996, nearly thirty years after the PBL movement started, Gwendie Camp was concerned that 'true PBL' was being watered down [3]. She insisted that unless PBL was 'active, adult-oriented, problem-centred, student-centred, collaborative, integrated, interdisciplinary and utilized small groups operating in a clinical context' it should not be called PBL. She correctly pointed out that if a PBL program was 'teacher-centred' rather than 'student-centred', the heart of 'pure' PBL would be lost [4]. Although very few would cavil at her concluding sentence there were many who objected to Camp's 'purist' approach. Ranald Macdonald was one [5]. Savin-Baden [6] also argued that PBL is an approach characterized by 'flexibility and diversity in the sense that it can be implemented in a variety of ways in and across different subjects and disciplines and in diverse contexts'. Boud and Feletti [7] pointed out that 'The principle behind PBL is that the starting point for learning should be a problem, a query or a puzzle that the learner wishes to solve'. We also argue that there can be a number of approaches and variations in the practice of PBL. Today a large number of disciplines use PBL, in different shapes and forms.

In Business and Economics many Faculties design their architectural space to allow for 'syndicate rooms' where students can work on problems either as one-off tasks or as a connected series of problems that make up a whole subject or curriculum. The table opposite, which provides a simple diagrammatic sketch of PBL is taken from the English Economics Network site that includes a handbook on PBL. The site details key features of PBL and reasons for using it. The link is http://www.economicsnetwork.ac.uk/handbook/pbl/21

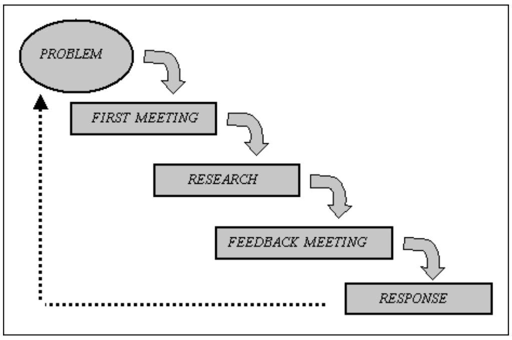

Table 1: A simple PBL model

In Engineering a particular form of Project Based Learning that has gathered momentum over the last 25 years is CDIO. The abbreviation stands for Conceive, Design, Implement and Operate and this model started as a curriculum project at Massachusetts Institute of Technology (MIT) in 1997. Since then it has grown into a worldwide movement in Engineering Education. CDIO and has just held its 10th international conference (Barcelona, 2014) and published a second edition of the CDIO book which outlines its principles and practice. It is now spread across a number of countries and is practised in 107 different Engineering Schools. The table below taken from the CDIO website provides a useful overview.

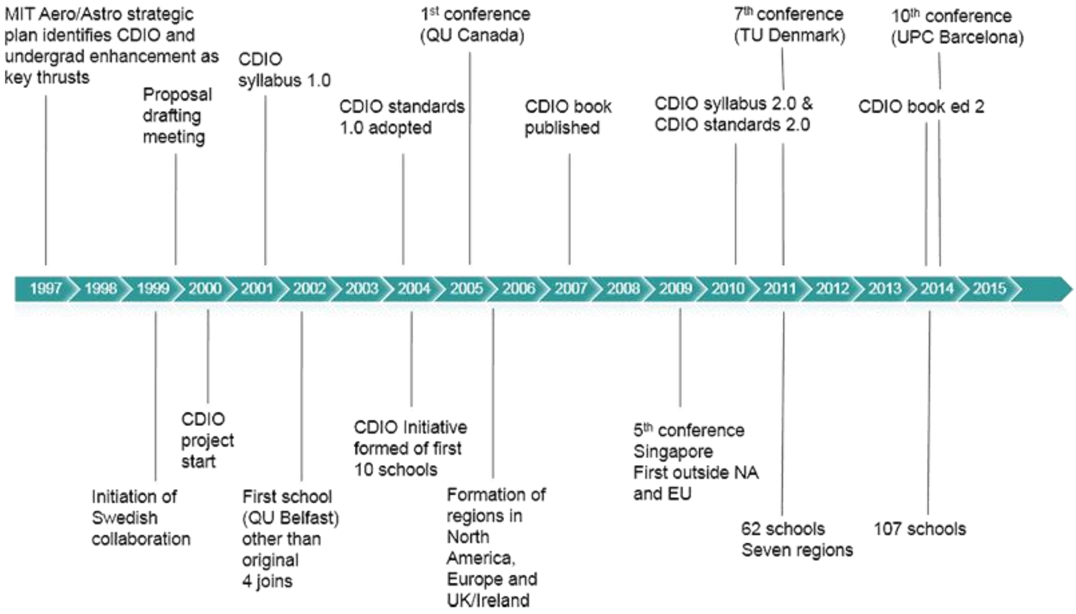

Table 2: CDIO history. Source: http://www.cdio.org/cdio-history

Engineering educators who promote this form of project based learning argue, as the McMaster staff did, that the pedagogical model emulates the way practitioners in their profession work. Doctors diagnose medical problems and try to find remedies. Engineers design, build and test products.

It is the nature of PBL to adapt to different settings, cultures, curricula and circumstances. Camp did everyone a favour by clearly showing that PBL has its theoretical origins in the conceptual work of adult educators like Malcolm Knowles [8], a constructivist epistemology [9] and in the psychological principles of learning [10]. Having a sound philosophical basis for PBL is important. However, none of those theories espouse a dogmatic approach. PBL should not become a straitjacket for educators. It is a practical, pedagogical paradigm robust enough to be adapted by a range of disciplines and for a variety of purposes. Both Problem and Project Based Learning enable educators to prepare their students for their future professional life as opposed to simply being able to pass exams. In the concluding part of our essay we encourage participants at this joint conference to reflect on their own practice and critically analyse what constitutes the key characteristics of an Active Learner in Engineering Education. More importantly we ask 'how can we, as educators, facilitate and encourage active learning?'.

Without getting bogged down in 'academic' detail it is worth comparing Project-Based and Problem-Based Learning in order to see how they can best serve the Active Learner in Engineering Education. In doing so we will answer, in a more general, theoretical way, the questions we have posed above. Are our two models the same or different? Both are concerned with engaging students in real world exercises to enhance their learning. Some tasks can be simulated, others require wider field experience in an actual workplace. We mentioned earlier that Higher Education tends to default to pen and paper exams. Both Project-Based and Problem-Based Learning emphasize performance based, authentic assessment.

We have already alluded to one of the more significant differences between the two models. Project-based learning usually has the creation of a product or an artefact as a goal. Although projects can differ widely students have to acquire the knowledge, skills and right values if they are to be successful in designing, building and testing their product. Problem-based learning, as the name suggests, begins with an issue or problem that the students need to solve or learn more about. Ill defined problems are often selected to ensure that the scenario or case study, if that is the format which is used, simulate real life complexities. In some instances the problems are actual problems that businesses want solved. Both forms of PBL can complement one another. Which is why it is fitting that the associations that represent research into PBL and Project Based Learning in Engineering Education should come together with ALE at this joint conference. Placing of the various keynotes at the intersection of the ALE workshop, the PBL Symposium and the Project Based Learning conference eloquently demonstrates how well all three support one another in their desire to activate learning in Engineering Education.

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IJCLEE/PAEE'2015 Workshop Submissions

Submissions accepted for the IJCLEE/PAEE'2015 workshop sessions.

A Student-Centered Approach to Designing Teaming Experiences: Research and Practice

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Abstract

We often approach teaming in course design with a very simple philosophy: If students are put on teams, they will learn teamwork skills and get the educational benefits of teaming. In reality, team dynamics are complex and course design influences which of the plausible benefits of teaming students actually obtain. In this workshop, we explore the design of teaming experiences from a pragmatic perspective. Participants experience first-hand some of the complexities of team dynamics in project-based learning; consider how instructor choices in course design enhance or diminish the effectiveness of teaming; learn about some of the relevant background research; and begin to situate their own curricular choices within a framework for scaffolding successful teaming experiences. Participants employ design thinking tools (student personas, interaction narratives) in order to explore what a team, and the individual students team members, might experience within a given teaming paradigm. We identify team pitfalls, share a broader set of insights about student engineering teams, and discuss specific approaches to scaffolding the development of teaming skills that responds specifically to the needs of particular students and particular institutions.

Keywords: teaming, teamwork, design thinking, personas, gender, student-centered research

1 Introduction

Team projects can be used to facilitate collaborative learning to develop or enhance a set of educational outcomes for all students. Alternately, team projects may be more performance-oriented, focused on the delivery of successful end products or developing students' ability to work professionally on teams. While team projects can do any of these things, they cannot generally do all of them simultaneously.

Different curricular designs support different learning outcomes: in the former case, students may have the opportunity to develop new skills and strengths, and in the latter students must play to their strengths to meet performance goals. Choices instructors make in setting up project based learning environments can have significant impact on the effectiveness of these environments at meeting educational goals. For example, in high-stakes, outcome-oriented teaming situations, it is common to see engineering coursework divided along stereotypically gendered lines, leading to differentiated learning experiences between male and female students.

It is rarely enough to introduce teaming, without additional attention to the impact of that factor in the experiences of participating students. The premise of this workshop is that conscious curricular choices can exacerbate or mitigate such effects. Participants will explore this premise through hands-on interaction, using design thinking tools, and through reflection and a framework-based approach to curriculum redesign.

2 Rationale

A number of trends are leading to a general increase in the number of teaming experiences in undergraduate engineering programs: first, as has been the case for many years, there is a continuing call from employers, accreditation agencies, and other stakeholders to *improve graduates' ability to work professionally on teams*. At the same time, the potential for project-based educational approaches to improve student engagement and motivation, and to allow students to apply and synthesize knowledge in more authentic settings is leading to increased teaming in order to *enable more authentic educational experiences*. And finally, there is wide recognition of the benefits of collaboration in learning; as a consequence, teaming is often introduced as a means of *improving other educational outcomes through collaborative learning*. And, while these benefits of teaming are all worthy, they can at times be in tension. In short, the role of teaming in an educational setting can be multi-faceted and complex.

Many instructors are, of course, thoughtful about the complexity of teaming, and they consider stages of team formation, team roles, the importance of peer feedback in teaming, and so forth. But as a community, we often approach teaming in course design with a very simple philosophy: *if students are put on teams, they will learn teamwork skills, get the educational benefits of teaming, etc.*

In this workshop, we will explore the design of teaming experiences, and the tensions that arise, as we try to address different outcomes. What happens after the team project has been assigned and the team has been formed? What challenges do students (as individuals) and student teams face when faced with a group they are supposed to work with, and a set of milestones and final deliverables? And how do we do this in a thoughtful way responds to students' needs, interests, and constraints, as well as a particular set of outcomes?

Participants will employ design thinking tools (student personas, interaction narratives) in order to explore what a team, and the individual students on the team, might experience within a given teaming framework. We'll identify the team pitfalls, and share a broader set of insights about student engineering teams. Finally, we'll discuss frameworks and specific approaches to scaffolding a teaming process and development of teaming skills that will let you think about how to respond specifically to the kinds of constraints and challenges students face at your particular institution.

This symposium will be based on two different interaction approaches between participants. One is the traditional paper sessions where participants can share their work and proposals. The other model of interaction results from our main goal of learning from each other and is based in workshop sessions of small groups working as "project teams".

3 Workshop Goals

This session has two primary goals. First, participants will reflect on and explore the extent to which a simplistic approach to design of teaming experiences can lead to undesirable outcomes, and the extent to which different outcomes associated with teamwork can often be in tension. Second, participants will explore promising approaches for designing team-based experiences that achieve specific goals, with a particular eye toward designing for learning goals as opposed to performance goals. Finally, we hope participants will have a chance to share their own experiences in this space and learn from each other -- while having a good time!

4 Workshop Agenda

Introduction: 10 minutes

Facilitators provide overview of the session, high level concepts, introduction of first activity

Creating a team interaction narrative, identifying pitfalls: 30 min

Using provided personas and an interaction narrative framework, teams of participants will imagine what a provided team-based activity might be like for students, and will identify ways in which the activity achieves or does not achieve its goals.

Designing for different outcomes: 10 minutes

Facilitators provide an overview of a framework for designing team-based experiences.

Activity Re-design: 20 min

Participants apply the framework and propose changes to better align the provided activity with alternative goals.

Conclude and Reflect: 10 min

This section has information relevant for participants' registration, both on web the platform and the symposium, and instructions for authors.

4.1 Presenters

Jessica Townsend (Associate Professor of Mechanical Engineering, Associate Dean for Curriculum and Academic Programs at Olin College) and Lynn Andrea Stein (Professor of Computer and Cognitive Science, Associate Dean and Director of the Collaboratory at Olin College) both joined Olin College early in the institution's history, and have worked extensively in faculty development and project-based curriculum design both at Olin, and in collaboration with faculty and institutions from around the world through Olin's Collaboratory.

Both have presented both traditional papers and special sessions at FIE previously, including a related session at FIE 2014. Stein and co-author Caitrin Lynch received the Helen Plants Award in 2013 for the special session, *Connecting with Community: Empathy, Experience, and Engineering with Elders*. Stein has previously presented research closely related to the session topic (see, for example, Evidence for the Persistent Effects of an Intervention to Mitigate Gender-Stereotypical Task Allocation Within Student Engineering Teams, FIE 2014).

4.2 Expected Outcomes

Participants will practice employing design thinking tools including student personas and interaction narratives.

Participants will be able to describe potential tensions between individual goals and team goals.

Participants will be able to describe some of the tradeoffs and potential pitfalls in the design of team-based experiences for different outcomes.
Participants will develop strategies for teaming to achieve particular outcomes.

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Unpacking the language of "Impact" and "Success" in Project-Based Learning Initiatives

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Abstract

Project-based learning (PBL) requires instructors to re-examine their perspectives on teaching. What counts as "success"? How should a course "impact" students, the institution, and the world? What language and practices do we use to describe and discuss these topics? In this workshop, facilitators will challenge participants to observe and disrupt their conversation patterns about "impact" and "success" in engineering education.

Keywords: impact, participation architecture, engineering education

1 Intended audience

This workshop is designed for instructors, administrators, and anyone else involved in decisions about what the words "impact" and "success" mean for a PBL curriculum. We invite participants to bring their own PBL projects as material to discuss using alternative conversation/participation architectures geared towards transformative learning and self-authorship.

2 Scope

Our goal is to help participants form a clearer idea of how they currently conceptualize and communicate "impact" and "success" for PBL initiatives (Siddiqui & Adams, 2013) and expose them to alternative participation infrastructures as tools they can use to reframe their thinking. The vocabulary of self-authorship (Baxter-Magolda & King, 2004) and transformative learning (Mezirow, 1991) will be introduced as tools to think with as we alternate between hands-on activities and reflective dialogues.

3 Workshop overview

The total workshop time is 90 minutes; facilitators will provide materials. We can accommodate 15-40 participants, and require a room with movable chairs and tables that can be grouped for discussion.

3.1 Activity 1: Divergent Thinking (minutes 0-20)

The first activity is a divergent thinking exercise that draws its participation architecture from improvisational theatre. Participants are seated in small groups and given a stack of cards with engineering innovations and artistic terms on them. (Examples: the internet, running water, a string quartet, street dance, etc.) Participants help each other create "impact analogies" for their PBL project: "My project is like ____, because ____."

Examples:

- My course redesign is like ballet: we're performing a difficult thing in front of our student audience, but need to make it look easy.
- My summer bridge program is like the flu vaccine, because it helps "protect" first-year students from environmental factors that often cause attrition.
- My flipped classroom is like indoor plumbing, because it turns a centralized activity into one that has round-the-clock individualized availability at home.

This activity serves as an icebreaker while simultaneously building critical consciousness of our language habits in engineering education. Participants explain their own engineering education projects to others while using "out of the box" language. Scope

This symposium will be based on two different interaction approaches between participants. One is the traditional paper sessions where participants can share their work and proposals. The other model of interaction results from our main goal of learning from each other and is based in workshop sessions of small groups working as "project teams".

3.2 Activity 2: Circle discussion (minutes 20-60)

The second activity uses the "Circle Way" (Baldwin, Linnea, & Wheatley, 2010), a participation architecture drawn from traditional tribal storytelling practice. "Circle Way" elements include an emphasis on intentional listening and an avoidance of "caretaking" or "problem-solving" behaviors ("let me help you fix that!"). It focuses on holding uncertainty within a conversation for extended periods of time. To do so, it employs communal pauses as a strategy for re-centering and speaking protocols that give each person multiple chances to voice their thoughts.

Participants will gather in circles, with at least one facilitator at each circle. Facilitators will give a brief overview of Circle format, then guide the group in rotating through the following roles:

- Host: convenes the discussion and poses a topic or question of deep inquiry to the group. (Facilitators will initially serve as Hosts.)
- Guardian: monitors the shared energy and attention of the circle, and calls for re-centering pauses when needed or as cued by other members of the group. For instance, a pause may be called to thank and honor a particularly brave moment of sharing. It may also be called to defuse tensions, provide breaks for physical fatigue, remind the group of discussion rules, or for any other reason.
- Scribe: records the sense of the group's conversation in any method they prefer. The focus is not on detailed factual reproduction for an external audience, but rather on enabling group members to re-visit moments of insight later on. We will use this architecture to reflect on what the "analogies" activity revealed about our PBL projects and our thought patterns around "impact" and "success."

The final few minutes of circle format will be spent discussing the format itself and its potential applications to our home settings, such as course discussions and committee meetings. In addition to facilitating reflection on our "impact" rhetoric, this activity is intended to give participants a lived experience of a different sort of conversational environment and to make-visible the underlying social rules that enable such an environment to occur.

3.3 Activity 3: Step-back peer review (minutes 60-90)

The final activity uses the "step-back" participation architecture from the Harvard Macy Institute. Participants take turns describing their PBL project to 2 other people. They then "step back" and listen to their 2-person "audience" discuss their project as if they were not in the room. Timing is as follows, given a group with 3 participants (A, B, and C):

- Presentation: 1 minute. Person A presents their PBL project to B and C. The time is deliberately kept short so there will be insufficient room to present the full idea.
- Step-back: 5 minutes. Person A shifts their chair backwards and silently listens while B and C discuss A's project as if A were not in the room. Person A is not allowed to speak, and B and C are not allowed to acknowledge A's presence.
- Response: 2 minutes. Person A rejoins the conversation and responds to the dialogue they overheard between B and C.

The workshop will conclude with a brief wrap-up and pointers to further resources for each of the participation architectures presented.

4 Expected outcomes

Participants will come away from the session with a clearer idea of how they currently conceptualize and communicate "impact" for their projects as well as alternate ideas for how they and others could conceptualize and communicate it. They will have had exposure to multiple frameworks and vocabularies for discussing impact, practice in switching between frames of reference during a peer-review dialogue, and a rich shared experience of engagement in self-authorship.

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IJCLEE/PAEE'2015 Full Papers Submissions (English)

Submissions accepted for the IJCLEE/PAEE'2015 papers sessions in English.

Learning and Teaching Guidelines for Engineering Students and Staff in Project/Design Based Learning

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Abstract

Engineering education faces several challenges, such as improving teaching methods to enhance students learning and engagement. The need for learning and teaching guidelines for engineering students and staff is to assist students to acquire and apply their professional skills, to assist staff to propose methods to assess and evaluate teaching effectiveness with modifications. On the other hand, industry began to realize about the inadequacy of career expected skills such as critical analysis, creative thinking, communication, teamwork and problem solving in engineering graduates. In an engineering curriculum, staff members have the responsibility to ensure students acquire clear, accurate and timely information concerning relevant program structure, practice, teaching quality and learning outcomes. The learning and teaching guidelines for engineering students and staff in a project oriented design based learning environment aims to improve teaching methods to enhance students learning outcomes. It helps students to acquire and apply their professional skills, and propose methods to assess and evaluate real world design problems. In Project Oriented Design Based Learning (PODBL), staff and students practice-engineering design in meaningful ways and can easily adapt to it. From the quantitative and qualitative analysis performed, the results are analysed and presented from a students' perspective and staff views about project oriented design based learning within the curriculum. Based on a number of detailed research studies performed by the authors, this paper will present learning and teaching guidelines for engineering students and staff in project-oriented design based curricula.

Keywords: project oriented design based learning; engineering education; learning and teaching guidelines.

1 Introduction

The learning and teaching guidelines for staff assist staff members to ensure the course design, program structure, teaching and learning assessment, which help students to be active learners. By practicing these guidelines, staff and students are supposed to work together in order to achieve a balanced learning and teaching process. Through learning and teaching guidelines, engineering students obtain an opportunity to gain self-knowledge that helps them attain professional skills and qualities as an engineering graduate. The analysed data gained from student perspectives using a paper-based survey, staff perceptions using face-to-face interviews, and industry views through industry-academic design forums. The focus of this research paper is to present individual learning and teaching guidelines for engineering students, staff in an engineering curriculum.

Through guidelines for the PODBL framework, students obtain an opportunity to gain self-knowledge that helps them attain professional skills and qualities as an engineering graduate. The guidelines for the PODBL framework assist staff members to ensure the course design, program structure, teaching and learning assessment will help students to learn. By practicing framework guidelines, staff and students are supposed to work together in order to achieve a balanced learning and teaching process. Academia believes that quality assurance in teaching and learning is a shared responsibility of teaching staff and academic managers. Both teaching staff and academic managers are responsible for ensuring program development, management, teaching and assessment enhances student engagement in the learning process. It is an interesting and challenging task for staff and students to practice a new learning & teaching process. The teachers find it interesting to implement the system and integrate engineering and technology into projects in meaningful ways. Staff members look at the method of learning through projects as a benefit for all stakeholders such as students, Industry, community and university through project oriented design based learning curricula.

2 Project Oriented Design Based Learning Curricula

Project Based Learning is perceived to be a student centred approach to learning. It is predominantly task oriented and facilitators often set the projects. In this scenario, students need to produce a solution to solve the project and are required to produce an outcome in the form of a report guided by the facilitators. Teaching is considered as input directing the learning process. The project is open ended and the focus is on the application and assimilation of previously acquired knowledge.

Design based learning (DBL) education is a form of project/problem based learning in which students gain knowledge while designing a solution (object or artifact or report) meaningful to the students. It involves collecting information, identifying a problem, suggesting ideas to solve it and evaluating the solutions given. Once students have chosen the problem to focus on, they design a solution to solve it. Finally, the students receive feedback on the effectiveness of their design both from the facilitator and from other participants. Design-based learning is especially used in scientific and engineering disciplines.

Engineering students require the opportunity to apply their knowledge to solve problems through project-based learning rather than problem solving activities as those do not provide a real outcome for evaluation (Solomon, 2003; Stojcevski, 2008; Vere, 2009). One of the greatest criticisms of traditional engineering pedagogy is that it is a theory based science model that does not prepare students for the 'practice of engineering'. Self-directed study is a large part of a student's responsibility in project based learning modules (Frank, Lavy, & Elata, 2003; Hadim & Esche, 2002; Hung., 2008; Stojcevski, 2008).

By engaging students in learning design, DBL provides an opportunity to experience individual, inventive and creative projects that initiates the learning process in relation to their preferences, learning styles and various skills. Yaron Dopplet (Doppelt, 2009) states that DBL is used to produce a curriculum that improves learning for all students in science education. Students are involved in solving a problem through a creative project and experience meaningful ideas that allows them to analyse a suitable solution for it. To provide students with better practise in design and technology, DBL has several advantages that meet social, economic and industry needs. It is also an active learning process which makes students practice and recognize different learning styles and team based activity supports learning and sharing through cooperative methods (Dopplet, 2008; Reynolds, Mehalik, Lovell, & Schunn, 2009).

3 Methodology

To develop framework guidelines for engineering students and staff, this research needs to obtain the perspectives of students' and staff about design based learning through projects. The questions covered here to obtain students' views were presented as paper-based surveys and staff perspectives were obtained by face-to-face interviews on design based learning in engineering education. The research consultation process needed ethics approval from the higher degree research ethics committee of the School of Engineering at Deakin University. This research also needed staff perspectives on design-based learning from other Australasian universities. From the quantitative and qualitative analysis performed, the results are analysed and presented from a students' perspective about project/design based learning within the curriculum. The research results are published in many conference and journal articles that supported to define the framework guidelines for PODBL (Chandrasekaran et al, 2013; Chandrasekaran et a 2013; Chandrasekaran et al, 2014; Chandrasekaran et al, 2013; Chandrasekaran et al, 2013; Chandrasekaran et al, 2013; Joordens et al, 2012).

4 PODBL Framework Guidelines

The project-oriented design based learning approach creates a boundary for student learning capabilities when programs are content driven and focused on engineering science and technology courses. PODBL is a structured framework, which will overcome insufficiency of design practice related to the industry requirements. For quality learning and teaching, a curriculum needs student and staff participation, industry collaboration, management support and social involvement. The PODBL framework guidelines have been developed with a diverse range of students' views, staff perceptions, industry expectations and social needs.

Chandrasekaran et al (Chandrasekaran et al, 2013; Chandrasekaran et al, 2013; Chandrasekaran et al, 2014; Chandrasekaran et al, 2013; Chandrasekaran et al, 2013; Chandrasekaran et al, 2013; Joordens et al, 2012) discussed the analysed data and published peer reviewed conference, journal articles nationally and internationally. The analysed data gained from student perspectives using a paper-based survey, staff perceptions using face-to-face interviews, and industry views through industry-academic design forums. The PODBL framework guidelines were based on these analysed data from students, staff and industry in a design oriented curriculum at Deakin. These guidelines are all practically described and are underpinned by constant engagement between students, staff, industry, faculty and for accreditation purposes.

4.1 Guidelines for Students

In PODBL, students learn engineering design using projects through self-directed learning and learning by doing. Figure 1 shows the PODBL framework guidelines for students. The guidelines below show how students will involve in a PODBL environment to enhance their learning outcomes. Learning begins with first year design training projects (1-4 weeks in each trimester), which educates students about engineering principles, fundamentals and the learning design process. Staff act as facilitators, which builds student capabilities to identify problems and solve the problem through analytical thinking.

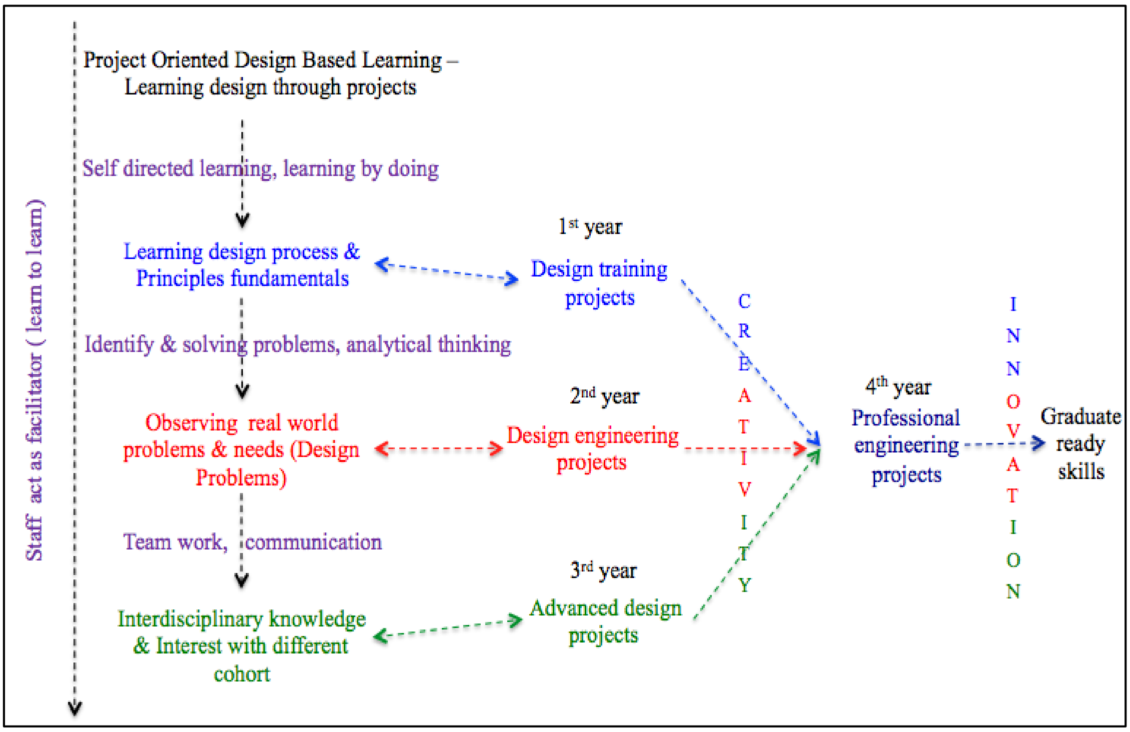

Figure 1: Students - PODBL framework guidelines

Second year design engineering projects (1-6 weeks) are more challenging, where students need to interact with their environment to observe real world problems and the needs of society. Students have to realize that actual design problem exists in every aspect of their daily life. Advanced design projects in the third year of engineering help students to work on projects across multi-discipline boundaries to acquire interdisciplinary knowledge, communication, and teamwork skills. In fourth year, the professional engineering projects are capstone projects from academia and industry collaboration.

4.1.1 Students Role in PODBL

All engineering curriculum has the responsibility of educating students in their engineering disciplines. Students have realised their need for the quality of learning and teaching. In each learning process, a student learns at their own pace and in their own learning style to achieve educational objectives. Through a chosen learning career path, students obtain a great opportunity to gain self-knowledge that helps them attain their full potential. The role of students in the Project Oriented Design Based Learning approach is as follows:

- Ability to observe and react in a professional environment (self-directed).
- Identify and solve problems with interactive knowledge.
- Getting involved with the practical application of knowledge.
- Being creative and innovative in solving design problems.
- Be aware of industry graduate expectations and be career focused.
- Seek support and guidance from staff members.
- Contribute engineering knowledge to the needs of society.
- Adapt to new values, customs, and learning styles in a working environment.

On-going personal and professional development helps students sustain life-long learning skills such as critical thinking, self-directed learning, interpersonal skills, self-confidence, creativity and innovation.

4.1.2 Learning through Projects in PODBL

Students are required to conduct research, demonstrate critical thinking and document sound analysis and judgment to support project decision-making. Students' define and scope their project, apply technical knowledge, assess safety and risks, prepare a feasible plan and schedule the implementation of the project in the project implementation phase. Students are required to work and learn autonomously, prepare and adhere to work and reporting schedules, communicate progress, and prepare reports and presentations. Projects provide useful evidence for prospective employers regarding competence in areas of mutual interest. The PODBL process consists of the following projects in undergraduate engineering:

- Design training projects – 1st year
- Design engineering projects – 2nd year
- Advanced design projects – 3rd year
- Professional engineering projects – final year

Learning through projects has a positive effect on student content knowledge and the development of skills such as collaboration, critical thinking, and problem solving which increases motivation and engagement. It is challenging for teachers finding hard to implement the system, to integrate technology into projects in meaningful ways. When we look at the method of learning through projects, it benefits all stakeholders, such as students, industry, community, and the university involved. It provides a framework for embedding experiential and rich learning activities integrated with discipline based curriculum that improves employment and career outcomes. The benefits of Project Oriented Design Based Learning includes enhancing students' participation in the learning process (active learning and self-learning), enhancing communication skills, addressing a wider set of learning styles, and promotion of critical and proactive thinking.

4.1.3 Graduate Ready Skills – Contemporary Needs

The Industry is looking for graduates who are ready to practice and perform essential competences such as practical knowledge, problem solving, teamwork, and innovative and creative designing of real-world projects (Deakin, 2012). In addition, both educators and industry representatives stated that students lack motivation in most cases due to the learning and teaching style they are exposed to. Thus, academics must focus on teaching engineering design practically. Staff should undergo practice rather than theory in the classroom.

In learning and teaching institutions, practicing design is one of the fundamental processes and activities in engineering and all other engineering activities are related to it. From industry's point of view, the following key skills are essential elements required for a successful Project Oriented Design Based Learning curriculum. These include creative & innovative skills, successful industry engagement, and awareness of design skills in the early years of engineering. A summary of findings from a qualitative analysis of an industry-academia design discussion forum shows a need for action on the skills such as creative & innovative, industry engagement, global perspective skills and awareness, internationalisation, connection between design and innovation, design awareness and communication & Project management skills.

By engaging industry with the academy, students will acquire global perspectives about the core attributes expected in future engineering jobs. In today's large-scale industry market, companies tend to prefer graduates with design skills attained through a project approach. The students realised the importance if communication and management skills in engineering practice. Thus, universities should open their doors and accept the challenges of involving students with industry experiences and expectations.

4.2 Guidelines for Staff

Staff teachings in an engineering curriculum have the responsibility to ensure students acquire clear, accurate and timely information concerning relevant program structure, practice, teaching quality and learning outcomes. In every implementation of new learning and teaching model, it is always a challenging task for staff to change their pedagogy practice to a new learning and teaching model. The readiness of staff for PODBL is shown in Figure 2.

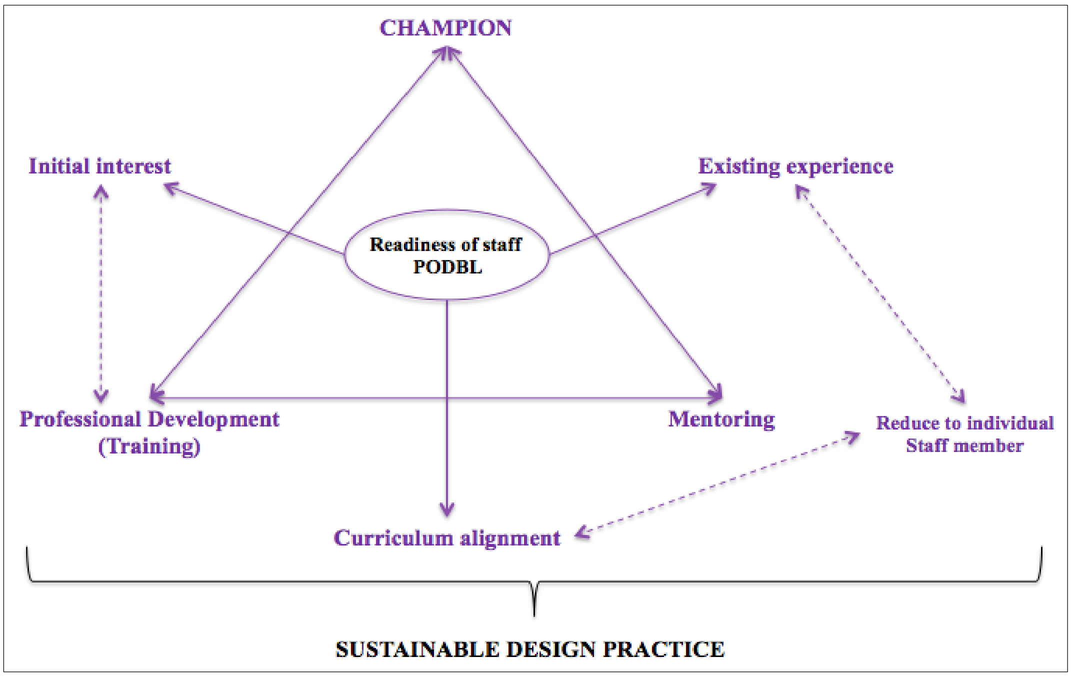

Figure 2: Staff - PODBL framework guidelines

With initial interest, and existing experience in learning and teaching, staff are encouraged to implement and practice PODBL in their respective program units called "Curriculum alignment". In PODBL, staff practice-engineering design in meaningful practice oriented tasks and assessment.

4.2.1 The Role of Staff in PODBL

Excellent learning and student engagement is a positive experience and also a result from quality teaching. Over many decades, researchers believe students will engage more deeply and learn more thoroughly when their teachers care about them to educate, learn, communicate and be innovative in the classroom. Academics need the perspectives of students' to analyse their experience in practicing and learning a particular approach. It also helps teachers to understand the level of expectation of students in their area of expertise. A teacher must ensure that course design, program structure, teaching and learning assessment should help learners to learn. The role of staff in PODBL is

- Developing and presenting consistent & creative resources for student learning.
- Implementing Project Oriented Design Based Learning approach to learning and teaching engineering course units.
- Communicating with students to meet their objectives and expectations for self-directed learning.
- Enhancing learning outcomes and teaching methods by actively engaging students.
- Inspiring and motivating students through project driven design based learning.

4.2.2 Professional Development

In academia, students and staff are supposed to work together in order to achieve a balanced learning and teaching process. By using different teaching and learning approaches, teachers are aware of escalating the student knowledge to fulfill current technology needs. In many cases, academic staff are responsible for setting high expectations in their classrooms. Sometimes staff are expected to teach subjects outside their expertise and in some cases, academic staff may experience a lack of confidence in their ability to teach such subjects yet are unwilling to seek professional development (Biggs, 2006). These professional development opportunities provide staff with valuable opportunities to enhance their personal teaching qualities, which helps them to achieve and follow a successful learning and teaching process.

At Deakin University, staff are encouraged to practice teaching and learning approaches that influence, motivate and inspire students to learn. Deakin Learning Futures provides a range of opportunities, events and services for staff to enhance their capability to be effective educators. In order to enhance and continue the engagement of students in learning and create active learners in the classroom, teachers need to teach each other through professional development workshops ward (Eliot & Howard, 2011).

Peer review of teaching is a well-established practice in many academic environments. In Australian universities, the aim of peer review teaching is to enhance learning and teaching. In peer reviewed teaching, staff members obtain an opportunity to share their professional responsibilities that enhance learning and teaching approaches. The benefits of peer reviewed teaching for individual staff members is shown below:

- Improving professional relationships with colleagues.
- Developing teaching practices from peer feedback.
- Sharing broader knowledge of curriculum and implementing new teaching ideas.
- Enhancing student assessment and learning outcomes.

4.2.3 Leadership for Learning and Teaching

Teachers have various levels of curriculum leadership qualities. A number of values and personalities make certain individuals ideal for leading teachers. An active teacher is an open minded and respectful person who obtains optimistic relationship with peers, students and parents. Teachers are always practicing how to improve their teaching techniques. Persuasiveness, open-mindedness, flexibility, confidence and expertise are fundamental attributes of a good teacher. However, working with other staff members is different from working with students. The ability to collaborate with others is an outstanding quality of leadership. To undertake a leadership role, people need to be an expert in curriculum planning, peer mentoring, assessment design and data analysis. The teacher leadership qualities are as follows:

- Passionate about learning and teaching.
- Initiating a peer-mentoring program – personal and professional development.
- Researching alternative classroom assessment methods and presenting these to management.
- Lead an initiative to formulate new learning and teaching methods for students.
- Developing procedures for staff to enhance their teaching abilities in the classroom.
- Encouraging best practices for student assessment and support on going changes to assessment practices.
- Developing various approaches to enhance the relationship between staff and students.
- Creating pathways to industry collaboration and encouraging peers to support industry projects.

4.2.4 Course Enhancement

Course enhancement is a systematic approach taken with all courses undergoing the process of creating course learning outcomes and standards. The course learning outcomes describe graduates' knowledge and capabilities they should acquire and be able to apply, and demonstrate at the completion of their course. Course learning outcomes and standards are derived and instructed by the relevant professional bodies. For example, the Australian Qualifications Framework (AQF) is the national policy for all regulated qualifications in Australian education and training. It provides all the standards for all Australian qualifications. In the higher education sector, the Tertiary Education Quality Standards Agency (TEQSA) provides national consistency in the regulation of higher education.

At Deakin University, students undertake common subjects in their first year and then choose a discipline to specialise in. This includes civil, electrical and electronics, mechanical or mechatronics engineering. This format allows students to make a more informed decision and to gain a broader base of knowledge in engineering. These undergraduate engineering courses are designed to meet the requirements of Engineers Australia.

5 Conclusion

Through learning and teaching guidelines, engineering students obtain an opportunity to gain self-knowledge that helps them attain professional skills and qualities as an engineering graduate. It is an interesting and challenging task for staff and students to practice a new learning & teaching process. The teachers find it interesting to implement the system and integrate engineering and technology into projects in meaningful ways. Staff members look at the method of learning through projects as a benefit for all stakeholders such as students, Industry, community and university through project oriented design based learning curricula. In Project Oriented Design Based Learning (PODBL), staff and students practice-engineering design in meaningful ways and can easily adapt to those learning and teaching guidelines.

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Flipping the engineering classroom: an analysis of a Brazilian university engineering program's experiment

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Abstract

With the ever growing number of transformative technologies and disruptive innovations, modern-day engineering professionals can no longer rely on sheer recollection of solved problems and implemented practices: they must develop abilities that go beyond the mere replication skills, and also include transference, integration and even design of methods and techniques to emergent challenges. However, as a general rule, engineering programs still favor instructivism (the unidirectional and linear transmission of fragmented content by the teacher) over constructivism (the dynamic and creative relationship between theory and practice by teacher-learner mutual interaction), leaving students with little room for active learning (critical reflection and self-discovery). Gathering steam for a few years now, flipped learning is a pedagogical approach in which the typical content understanding and application cycle is inverted: by granting students access to educational materials before class and moving homework into the classroom, it has been allowing them to (inter)actively clarify and apply concepts and practices during class with teachers acting as facilitators. The purpose of this paper is to analyze a Brazilian university engineering program's attempt to flip the classes in its courses. Examined data indicate that, although, in a strict sense, the engineering program's experiment failed to meet the basic criterion that out-of-class learning materials are provided in the form of videos and interactive tools, it was able to successfully flip its classroom, by 1) devoting class time to application of concepts by the students and allowing more time for one-on-one teacher-student interaction; 2) developing group-based activities and teachers' promotion of contextualized discussions; and 3) leading to a positive impact on the learners' adaptation of underlying theories to their individual cognitive structures.

Keywords: engineering education; constructivism; flipped learning; engineering teaching and learning.

1 Introduction

As technology and innovation increasingly become the drivers of global economy, effective human action is becoming less and less related to doings (which require memorization and reproduction skills) and more and more associated to interventions (which demand the ability to creatively adapt knowledge to new contexts).

This is especially true in engineering, where mere recollection of solved problems and direct transfer of previously implemented procedures and solutions have not been enough to cope with modern-day challenges, filled with uncertainty, partial information and competing demands.

However, more often than not, universities and engineering programs around the world still do not enable students to look for solutions to daily problems by means of a dynamic and critical relationship between theory and practice, favoring instead the unidirectional and linear transmission of fragmented content.

In most classrooms, instructivism (the teacher-directed purposeful study of planned curricula) hampers constructivism (the learner-driven generation of knowledge and meaning from an interaction between experiences and ideas), leaving students with little room for active learning (critical reflection and self-discovery) (Nikitina, 2010; Porcaro, 2011).

Luckily, the inadequacy of this notion of education as a teacher-centered product rather than a student-centered process has been challenged by teachers who, abandoning decontextualized and one-way teaching, have been striving to promote conscious, integrated and collaborative learning.

Gathering steam for a few years now, flipped learning is a pedagogical approach in which the typical content understanding and application cycle is inverted (Table 1), by 1) granting students access to learning materials in the form of videos and interactive tools before class; and 2) moving homework into the classroom. (Flipped Learning Network, 2014; Tucker, 2012).

Table 1: Traditional and flipped class approaches (Adapted from Bishop & Verleger, 2013).

	Inside Class	Outside Class
Traditional Approach	Lectures and Reading Materials	Learning Tasks and Practice Exercises
Flipped Approach	Learning Tasks and Practice Exercises	Videos and Interactive Tools

Furthermore, besides re-arranging activities, moving direct instruction from the common to the single learning space (Basic Flipping, in Table 2), flipped learning seeks to transform the communal space into an interactive contextualized hands-on learning setting, where teachers (with more time for one-on-one teacher-student interaction) can better guide students as they critically apply concepts and creatively develop projects (Full Flipping, in Table 2) (Bergmann & Sams, 2012).

Table 2: Basic and full flipped classes (Adapted from Bishop & Verleger, 2013).

	Basic Flipping	Full Flipping
Learning Space	Isolated Learning	Collaborative Learning
Teacher's Role	Learning Source (Teacher-Centered)	Learning Facilitator (Student-Centered)
Student's Role	Passive (Concepts Application/Reproduction)	Active (Critical/Creative Adaptation)

Therefore, due to its potential of allowing more effective classroom activities – on the one hand freeing up teachers' time to provide formative feedback and more personalized support to learners; and, on the other hand, giving students more control over their own learning – flipped learning has received much appraisal worldwide.

However, although very promising, flipped learning is still uncharted territory, requiring much analysis and discussion on the successes and setbacks encountered in its implementation, so that it can be further and better developed on a strong evidence-based protocol.

The purpose of this paper is to contribute to this effort by presenting how and with what results a Brazilian private university, which decided to venture into this unfamiliar ground, is implementing flipped learning in many of its programs, including engineering, focus of this research.

2 Methods

As the research aimed at investigating how flipped learning is being adopted by the engineering program of a Brazilian university, meaning to contribute to the consolidation of a scientific basis, both in its theoretical foundation and practical application, it characterized a descriptive study (Vergara, 1998).

As method of approach – the more abstract and broader methodological behavior for examining events (Marconi & Lakatos, 2006) – the study relied on the inductive method, which constructs or evaluates general propositions that are derived from specific examples (Fachin, 2005).

As method of procedure – the methodological behavior adopted in the more concrete phases of a study (Marconi & Lakatos, 2004) – the research was based on the observational method, which aims to accurately capture the essential and accidental aspects of phenomena in the empirical context (Fachin, 2005).

As method of investigation – the methodological behavior regarding the way the researcher intervenes in reality (Vergara, 2005) – this investigation made use of fieldwork, which is an empirical research in which primary data is collected where the studied phenomena are likely to occur (Fachin, 2005).

From among the different techniques for data collection, this study used closed and open questionnaires: in the closed questionnaire, respondents agreed or disagreed with given statements; in the open questionnaire, follow-up questions allowed respondents to freely express their feelings and thoughts (Marconi & Lakatos, 1990).

With regard to the techniques for data analysis, both the quantitative – the objective analysis of facts which can be measured and expressed numerically (Gil, 2006) – and the qualitative – the subjective detailed description of observed phenomena (Gil, 2006) – treatments were applied.

Once this study endeavored to stimulate the development of educational models that bring less domination and exclusion, and because it rejected unilateral views and oppressive actions, perceived as useless in today's world, it adopted a critical orientation to teaching and learning (Baptisa dos Santos *et al.*, 2010).

3 Results

The flipped learning experiment in the studied engineering program concentrated on the first term, which offers part of the basic disciplines of its four courses (civil, electrical, mechanical and production engineering), from whose population 272 students and 21 teachers agreed to take part in this research.

In order to describe how the flipped learning experiment was conducted and what its results were, this section is divided into five parts: 1) outlining of the engineering program's experiment; 2) development of the data collection instruments; 3) gathering of the perceptions of students on the experiment; 4) gathering of the perceptions of teachers on the experiment; and 5) analysis of students' performance after the experiment.

3.1 Outlining of the Engineering Program's Experiment

The engineering program's flipped learning experiment followed the general pedagogical model of flipped classrooms (learning materials are accessed by the students outside the classroom, while inside-the-classroom time is devoted to exercises), and its structure and actual practices are shown in Table 3.

Table 3: Structure and actual practices of the engineering program's flipped learning experiment.

Structure	Actual Practices
Students' access to outside-the-classroom learning materials was mostly in the written form, although there were a few recommended or recorded videos by their teachers.	Usually, because of their jobs (as they had to work to pay for tuition), students could not go through all outside-the-classroom learning materials: teachers usually had to resort to short lectures inside the classroom.
There was no online quiz that offered students immediate feedback on whether any important points regarding the outside-the-classroom learning materials had been missed.	Usually, because of their jobs (as they had to work to pay for tuition), even students who could go through all outside-the classroom materials sometimes misunderstood some basic concepts or practices.
Students of the same class had access to a forum in the university's virtual learning environment, where they could discuss doubts or interesting topics among themselves.	Usually, because of their jobs (as they had to work to pay for tuition), students' participation in the forum was below the engineering program's expectations (either quantitatively or qualitatively).
Teachers could view their student's posts in the forum for later use inside the classroom.	Teachers usually started their classes interactively clearing the doubts and trying to promote contextualized discussions of interesting topics posted by the students in the forum.

3.2 Development of the data collection instruments

For a more structured and directed gathering of the perceptions of students and teachers on the engineering program's experiment, a closed questionnaire (Table 4) was created so that they could indicate their level of agreement (three-point Likert scale) with given statements regarding traditional teaching and flipped learning (basic and full) approaches.

Table 4: Closed questionnaire.

		☹	😐	☺	
1	Lectures and reading materials are provided inside the classroom.				***Traditional Approach***
2	Learning tasks and practice exercises are performed outside the classroom.				
3	Lectures and reading materials are provided outside the classroom.				***Basic Flipping Approach***
4	Learning tasks and practice exercises are performed inside the classroom.				
5	Group-based interactive learning activities are often employed.				***Full Flipping Approach***
6	Teachers propose questions/projects, stimulating and guiding discoveries.				
7	Students critically apply concepts and creatively develop projects.				

☹ I totally disagree. 😐 I don't know. ☺ I totally agree.

Questions 1 and 2 sought to determine the occurrence of elements from the Traditional Approach in the engineering program's experiment; questions 3 and 4 aimed at identifying the presence of elements from the Basic Flipping Approach in the engineering program's experiment; and questions 5, 6 and 7 tried to detect the existence of elements from the Full Flipping Approach in the studied engineering program's experiment.

For a more flexible and stimulating gathering of the perceptions of students and teachers on the engineering program's experiment, an open questionnaire (Table 5) was built in order to capture their personal opinions and insights.

Table 5: Open questionnaire.

1	The most positive aspect(s) of the educational approach adopted by the engineering program is(are): ***personal opinion***
2	The least positive aspect(s) of the educational approach adopted by the engineering program is(are): ***personal opinion***
3	My suggestion(s) for improving the educational approach adopted by the engineering program is(are): ***insight***

3.3 Gathering of the Perceptions of Students on the Experiment

Table 6 synthesizes the students' responses to the closed questionnaire.

Table 6: Students' responses to the closed questionnaire.

#	Statement	☹	😐	☺	
1	Learning materials are provided inside the classroom.	83%	1%	16%	*Traditional Approach*
2	Learning tasks and practice exercises are performed outside the classroom.	81%	1%	18%	
3	Learning materials are provided outside the classroom.	16%	1%	83%	*Basic Flipping Approach*
4	Learning tasks and practice exercises are performed inside the classroom.	15%	1%	84%	
5	Group-based interactive learning activities are often employed.	17%	0%	83%	*Full Flipping Approach*
6	Teachers propose questions/projects, stimulating and guiding discoveries.	23%	0%	77%	
7	Students critically apply concepts and creatively develop projects.	29%	2%	69%	

☹ I totally disagree. 😐 I don't know. ☺ I totally agree.

Table 7 synthesizes the students' responses to the open questionnaire.

Table 7: Students' responses to the open questionnaire.

1	The most positive aspect(s) of the educational approach adopted by the engineering program is(are): ***Group-Based Activities.*** ***Teachers' Promotion of Contextualized Discussions.***
2	The least positive aspect(s) of the educational approach adopted by the engineering program is(are): ***Long Outside-the-Classroom Reading Materials.*** ***Few Outside-the-Classroom Videos.*** ***No Online Quiz on Outside-the-Classroom Learning Materials.***
3	My suggestion(s) for improving the educational approach adopted by the engineering program is(are): ***More Real-Life Tasks.*** ***More Hands-On Activities.***

3.4 Gathering of the Perceptions of Teachers on the Experiment

Table 8 synthesizes the teachers' responses to the closed questionnaire.

Table 8: Teachers' responses to the closed questionnaire.

#	Statement	☹	😐	☺	
1	Learning materials are provided inside the classroom.	91%	0%	9%	*Traditional Approach*
2	Learning tasks and practice exercises are performed outside the classroom.	90%	0%	10%	
3	Learning materials are provided outside the classroom.	8%	0%	92%	*Basic Flipping Approach*
4	Learning tasks and practice exercises are performed inside the classroom.	7%	0%	93%	
5	Group-based interactive learning activities are often employed.	4%	0%	96%	*Full Flipping Approach*
6	Teachers propose questions/projects, stimulating and guiding discoveries.	5%	0%	95%	
7	Students critically apply concepts and creatively develop projects.	17%	2%	81%	

☹ I totally disagree. 😐 I don't know. ☺ I totally agree.

Table 9 synthesizes the teachers' responses to the open questionnaire.

Table 9: Teachers' responses to the open questionnaire.

1	The most positive aspect(s) of the educational approach adopted by the engineering program is(are): ***Class time devoted to application of concepts by the students.*** ***More time for one-on-one teacher-student interaction.***
2	The least positive aspect(s) of the educational approach adopted by the engineering program is(are): ***Outside-the-Classroom Learning Materials Heavily Based on Long Written Texts.*** ***No Online Quiz on Outside-the-Classroom Learning Materials.***
3	My suggestion(s) for improving the educational approach adopted by the engineering program is(are): ***Replace Outside-the-Classroom Reading Materials by Videos.*** ***Increase opportunities for meaningful and collaborative activities.***

3.5 Analysis of students' performance after the experiment

In order to analyze students' performance (Table 10), a historical average of the term grades obtained by the students in each of the courses of the engineering program (before the experiment) was compared to the average term grades obtained by them after the experiment.

Table 10: Students' performance after the experiment.

Courses	Students' Term Grades After the Experiment
Civil Engineering	Up 18,18% in relation to the historical term grades average.
Electrical Engineering	Up 9,09% in relation to the historical term grades average.
Mechanical Engineering	Up 8,33% in relation to the historical term grades average.
Production Engineering	Up 9,09% in relation to the historical term grades average.

4 Discussion

In order to discuss the engineering program flipped learning experiment's results, this section is divided into four parts: 1) analysis of the students' perceptions on the experiment; 2) analysis of the teachers' perceptions on the experiment 3) examination of students' performance after the experiment; and 4) general evaluation of the experiment's results.

4.1 Analysis of the students' perceptions on the experiment

Analysis of the students' perception on the presence of elements of the Traditional Approach (questions 1 and 2 in the closed questionnaire) revealed (Figure 1) that, for the majority of them, the experiment adopted a different approach.

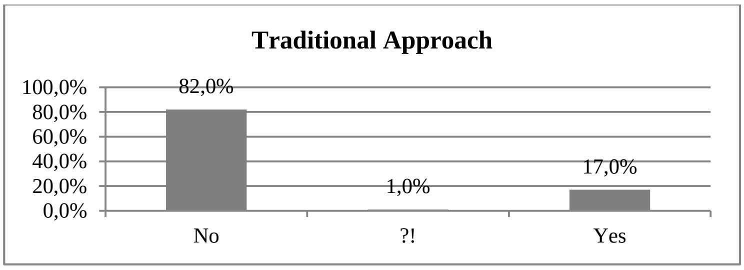

Figure 1: Students' perception on the presence of elements of the Traditional Approach.

Analysis of the students' perception on the implementation of the Basic Flipping Approach (questions 3 and 4 in the closed questionnaire) indicated (Figure 2) that, for the majority of them, the experiment took the fundamental steps toward flipped learning.

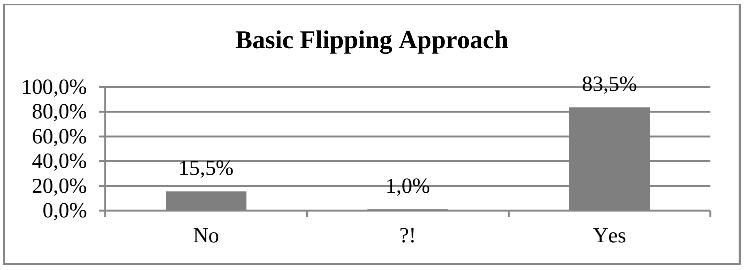

Figure 2: Students' perception on the implementation of the Basic Flipping Approach.

Analysis of the students' perception on the accomplishment of the Full Flipping Approach (questions 5, 6 and 7 in the closed questionnaire) showed (Figures 3a, 3b and 3c) that, for the majority of them, the experiment was able not only to invert the classroom, but also to create an interactive learning setting, with teachers guiding students in the critical application of concepts and in the creative development of projects.

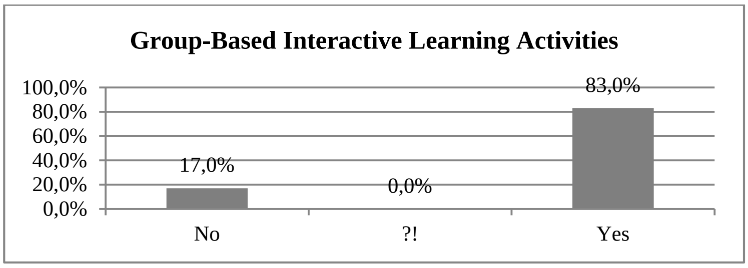

Figure 3a: Students' perception on the accomplishment of the Full Flipping Approach – learning activities.

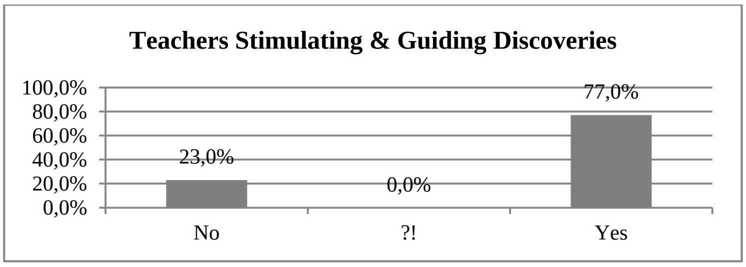

Figure 3b: Students' perception on the accomplishment of the Full Flipping Approach – teachers' roles.

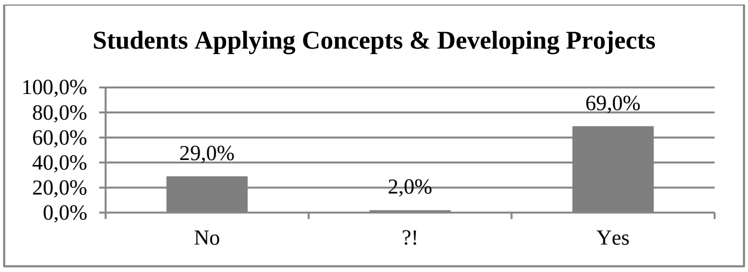

Figure 3c: Students' perception on the accomplishment of the Full Flipping Approach – practical application of theory.

Analysis of the student's responses to the open questionnaire makes it possible to infer that:

- group-based activities and teachers' promotion of contextualized discussions (traces of the Full Flipping Approach) were actually part of their routine, and highly appreciated by them;

- the absence of videos and interactive tools (hallmarks of the Flipping Approach) were perceived as a serious limitation of the experiment;

- students felt the need for an even more dynamic and critical relationship between theory and practice, by means of more real-life tasks and more hands-on activities.

4.2 Analysis of the teachers' perceptions on the experiment

Analysis of the teachers' perception on the presence of elements of the Traditional Approach (questions 1 and 2 in the closed questionnaire) revealed (Figure 4) that, for the majority of them, the experiment adopted a different approach.

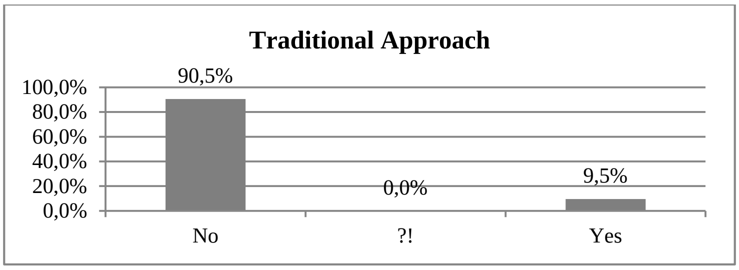

Figure 4: Teachers' perception on the presence of elements of the Traditional Approach.

Analysis of the teachers' perception on the implementation of the Basic Flipping Approach (questions 3 and 4 in the closed questionnaire) indicated (Figure 5) that, for the majority of them, the experiment took the fundamental steps toward flipped learning.

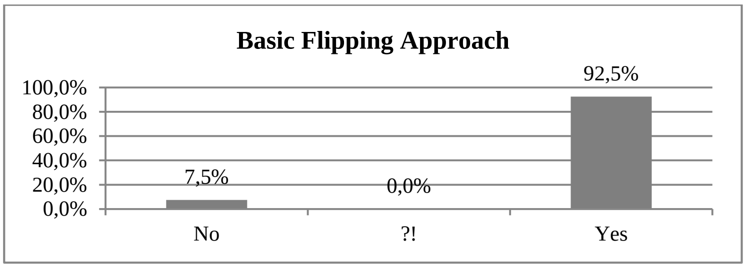

Figure 5: Teachers' perception on the implementation of the Basic Flipping Approach.

Analysis of the teachers' perception on the accomplishment of the Full Flipping Approach (questions 5, 6 and 7 in the closed questionnaire) showed (Figures 6a, 6b and 6c) that, for the majority of them, the experiment was able not only to invert the classroom, but also to create an interactive learning setting, with teachers guiding students in the critical application of concepts and in the creative development of projects.

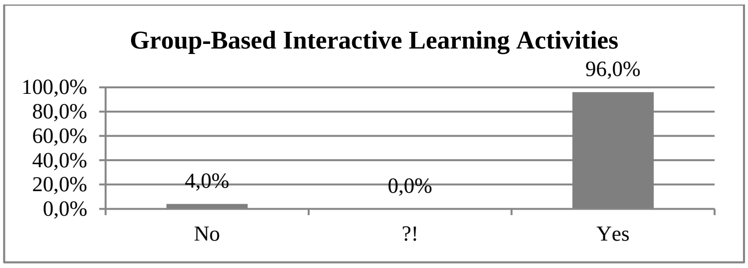

Figure 6a: Teachers' perception on the accomplishment of the Full Flipping Approach – learning activities.

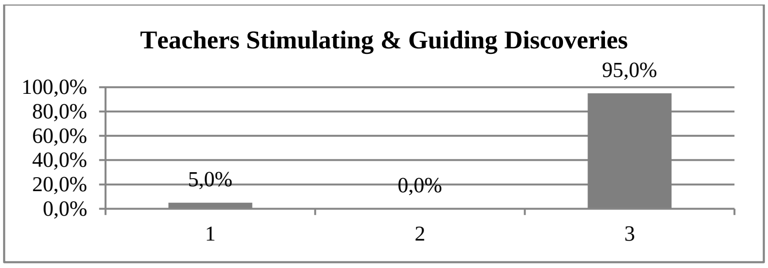

Figure 6b: Teachers' perception on the accomplishment of the Full Flipping Approach – teachers' roles.

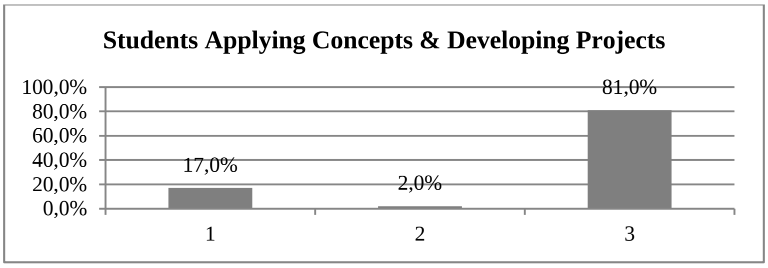

Figure 6c: Teachers' perception on the accomplishment of the Full Flipping Approach – practical application of theory.

Analysis of the teachers' responses to the open questionnaire makes it possible to infer that:

- class time devoted to application of concepts by the students and more time for one-on-one teacher-student interaction (traces of the Full Flipping Approach) were actually part of their routine, and highly appreciated by them;

- the absence of videos and interactive tools (hallmarks of the Flipping Approach) were perceived as a serious limitation of the experiment;

- teachers felt the need/opportunity for a more dynamic and critical relationship between theory and practice, by means of more meaningful and collaborative activities.

4.3 Examination of students' performance after the experiment

An examination of the students' performance after the experiment (Figure 7) makes it possible to infer that flipping the classroom had a positive impact on the learners' adaptation of underlying theories to their individual cognitive structures.

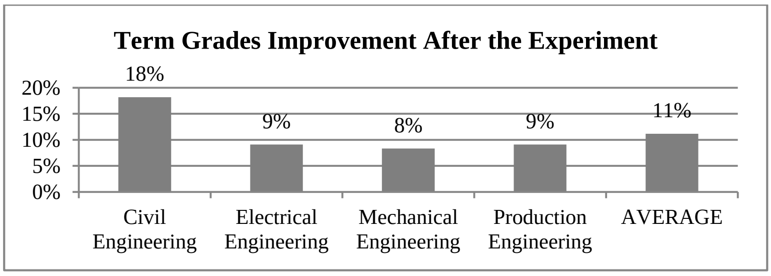

Figure 7: Students' performance after the experiment.

4.4 General evaluation of the experiment's results

In face of the analyzed data, it can be argued that, although, in a strict sense, the engineering program's experiment failed to meet the basic criterion that out-of-class learning materials are provided in the form of videos and interactive tools, it can still be considered a successful case of flipped classroom, as students' interaction with one another in inside-the classroom hands-on activities increased, with teachers functioning as facilitators, while encouraging them in individual inquiry and collaborative effort.

In this sense, it is interesting to note that the engineering programs' experiment did not follow the usual path for flipping the classroom reported in the literature: first, the basic flipping (emphasis on granting students access to learning materials outside the classroom), then the full flipping (emphasis on the development of a student-centered active learning environment).

So, even though the absence of videos and interactive tools were perceived as a serious limitation of the experiment by students and teachers, the results from this study are promising.

However, while the results from this study are inspiring for all those looking for more effective ways of teaching and learning engineering, this is not sufficient evidence to warrant generalization far beyond this situation, and, therefore, additional studies are needed.

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Process of structuring the course, idealization and adoption of learning space: the experience in adopting PBL in Fluid Mechanics Course

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Abstract

The paper aims to present information relating the experience of Brazilian Higher Education Institution, confessional character, implementing a new model curriculum. The HEI was started in 2011 six new careers in Engineering, at campus São Joaquim: Industrial, Mechanical, Electrical, Electronics, Civil and Informatics, all inspired at the CDIO approach. It proposes to share the experience and the necessary customization to the particular environment. The framework is based on strong interdisciplinary and transdisciplinary each school semester, consolidated on a project to each of these periods to which are related to the specific contributions for the disciplines of the curricular unit. Specifically, this paper is to present the experience in adopting PBL in subjects pertaining to structuring the course, specifically in Fluid Mechanics. The paper discusses the process of structuring the course, idealization and adoption of learning spaces, different of conventional lecture room, like the "Design Thinking Lab", the means of assessment, implementation and results. The environment in which the experiment takes place is a higher education in large classes (question: can we turn large classes) and high heterogeneity in basic education as students with a smattering of Math and Physics, typical problems of developing countries like Brazil. The results we present relate primarily to the prospects of students in relation to a set of key aspects for understanding the process of implementing the initiative and its impact. The re-engineering of programs, even if made easier by starting from scratch, is an ambitious project and UNISAL seeks to be in the forefront of this educational process, working in a structured and evolutionary way, covering programs in many disciplines, involving both teaching the process of evaluating the students established a continuous and formative way, following all the steps of formation of knowledge.

Keywords: active learning; engineering education; Salesian, Brazilian HEI, project approaches.

1 Introduction

The Salesian University Center of São Paulo (UNISAL) is a private, non-profit religiously- affiliated university that is part of a set of 79 Salesian universities in the Americas, Asia, Africa, Europe and Oceania. It is a medium-sized university by Brazilian standards, with close to 13,000 students at four university campuses. The Salesian passion – the education of young people – has origins in the founder of the congregation, Saint João Bosco and is the inspiration of all of its actions. The integration of knowledge, the dialogue between faith and reason, continuous search for truth, ethical development, the spirit of liberty and charity, mutual respect and the promotion of human rights characterize and animate UNISAL as a knowledge center that gives flavor to studying and research and promotes the acquisition of real-life knowledge.

In 2010, the Lorena campus decided to create courses in the engineering area. The Industrial Engineering program was started in 2011, and immediately following courses of Civil, Electrical, Electronic and Computer Engineering were added in 2012. Finally, in 2013, a program in Mechanical Engineering was added to the university's portfolio.

The Brazilian educational environment at the time these programs were introduced, not unlike the present day, was characterized by challenges, opportunities and constraints. Statistics from CONFEA (the Brazilian Federal Council of Engineering) count the number of engineers currently at 706,000, equivalent to six per thousand economically active people. To these 20,000 new engineering graduates are added every year. A key detail: in Brazil almost half of the engineers opt for Civil Engineering while in developed countries a large percentage choose disciplines closely linked to high-tech. However, challenges in Latin America such as social inequality, economic stagnation and shocks in the interaction between man and ecology should seek to confront these problems through engineering and technology. Finally, this scenario of not having enough engineers nor even engineering students to meet the needs of the country to incorporate technology, adds to the quality problem that has affected much of higher education. The deficiencies in primary and secondary education are carried over into the university level.

It is true that much of the crisis faced by Brazilian Engineering has its origin in elementary and secondary education, where "math aversion syndrome" is a bigger problem that lack of verbal or reading skills. The dropout rate of about 50% of engineering students over the first two years of the program has to do mainly with the poor preparation in math skills and the cumulative deficiencies in language skills (Inova Engenharia, 2006). As a result, the new courses, from conception, were defined using other paradigms. From the beginning, the programs were designed with the conviction that it would be necessary to introduce practical and contextual content as an essential factor to enable the assimilation of theoretical concepts in a practical manner. Besides this, it would be an important motivating factor for the student, helping to reduce dropout rates. The designed association of theoretical and practical activities enables the future professional to intervene in a practical way, mastering the nuances of reality through simulated activities such as exercises, papers, case studies, and practices not directly associated with the theoretical content of the courses used. The current prevailing model for training engineers provides the student with only a "two-dimensional" representation, when reality is three-dimensional and complex. Without a connection to practical reality, theory loses its role as an important tool for understanding.

According Litzinger et al. (2011) point out the need to build systematic curriculum design processes for an enlarged application of successful learning processes. Operations management concepts have been applied to strategy, design, planning, operation and evaluation of different types of services in HE organizations, but not seriously in academic learning services. The learning context, and in particular, the PBL context, requires an analysis process for characterization and identification of key aspects of the learning process. The broader context of the learning processes, the course curriculum, must also be characterised in order to build an adequate perspective of curriculum development. Relating curriculum development with service design models will allow for a systematic curriculum design process in a PBL context.

2 Desired Competences for Graduates: UNISAL Approach

The effectiveness and sustainability of the new courses would have to be supported by the ability to identify necessary changes and make sure they taken account of; one would not expect different results if the same traditional paradigms were maintained. On the other hand, the opportunity to start from scratch provided an enthusiastic motivation for change.

The strategy was to seek innovative and modern experiences to incorporate into the new programs. Literature searches, benchmarking and visits to institutes of higher education in and outside of Brazil, all oriented to create an innovative model.

In the first steps of program design, the definition of the desired profile for graduates of the courses was carried out. For Maximiano (2004) "Skills are knowledge, skills and attitudes necessary for a person to perform activities". Therefore, competencies are developed through learning and work experience, formal and informal education, and family and social life. Competence is knowing how to act in the face of complex situations and knowing how to mobilize knowledge, skills, attitudes and resources (technological, financial, marketing and human) to add value to different kinds of organizations of and become responsible for this while at the same time that also increasing their social value. The greater the complexity of the situations, more intensely knowledge, attitudes and skills are modified (Santos, 2003). From the competencies originally defined by Olin College (Miller, 2005) additional insights regarding the curriculum came from ABEPRO (the Brazilian Association of Production Engineering), and CREA-SP (the Regional Council of Engineering of São Paulo). Stakeholders were consulted through trade associations and this culminated in the establishment of an External Board made up of executives, officials and industry leaders, which defined the skills, abilities and attitudes that should be attained by graduates of engineering programs in the UNISAL Lorena. These are defined in Table 1.

Table 1. Competency Requirements for the Graduate

Competencies	Graduates should be able to...
Qualitative Analysis	analyze and solve problems in engineering and other disciplines qualitatively, including estimation, analysis with uncertainty, and qualitative prediction and visual thinking
Quantitative Analysis	analyze and to solve problems in engineering and other disciplines quantitatively, including use of appropriate tools, quantitative modeling, numerical problem solving, and experimentation.
Teamwork	contribute effectively in a variety of roles on teams, including multi-disciplinary teams.
Communication	convey information and ideas effectively, to a variety of audiences, using written, oral, and visual and graphical communication.
Understanding of Context	demonstrate understanding of the ethical, professional, business, social, and cultural contexts of engineering and other disciplines, and able to articulate his or her own professional and ethical responsibilities

Table 2. Competency Requirements for the Graduate (cont.)

Competencies	Graduates should be able to...
Lifelong Learning	identify and address their own educational needs in a changing world, including awareness of personal attributes, fluency in use of information sources, career planning, and self-directed learning.
Design	develop creative, effective designs that solve real problems though concept creation, problem formulation, application of other competencies, balancing tradeoffs, and craftsmanship.
Diagnosis	identify and resolve problems within complex systems through problem identification, formation and testing of a hypothesis, and recommending solutions.
Opportunity Assessment and Development	identify opportunities, to predict challenges and costs associated with the pursuit of opportunities, and to muster resources in response to opportunities.

Source: Adapted from Miller (2005) and Lourenço et al (2014)

In Table 1 we present the competencies which comprise whole education, the purpose of which is creating engineering graduates qualified in the "design, design, implementation and operation" of complex systems and products, especially in collaborative environments.

UNISAL represented the desired profile of the graduating student as illustrated in Figure . At the base is a “whole” education; this is the structural feature of the desired profile of the student upon completing a UNISAL program and it is guided by the institutional mission. We understand “whole” to mean consistent theoretical training, the development and skills and competencies, unity of theory and practice, the development of strong and Christian ethics, and social and political commitment. The purpose of this is to train professionals and qualified experts to join professional sectors and to participate in the development and transformation of Brazilian society as autonomous individuals. In Table 1 we present the competencies which comprise whole education, the purpose of which is creating engineering graduates qualified in the "design, design, implementation and operation" of complex systems and products, especially in collaborative environments.

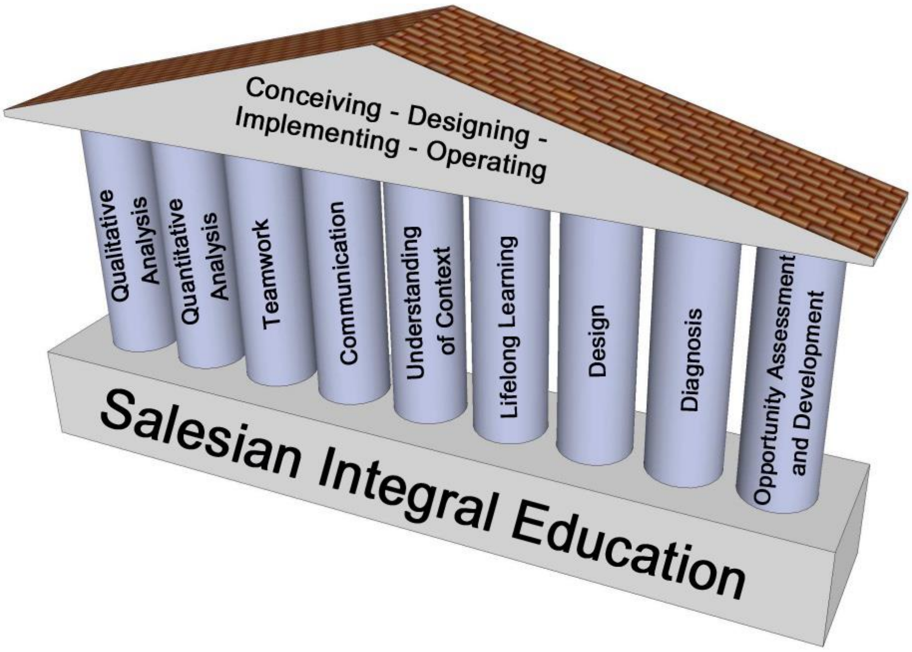

Figure 1. Graduates' Profile of UNISAL Engineering Programs

3 Interdisciplinary and active learning

The systematic and planned use of teaching methodologies based on Active Learning was one of the foundations of the pedagogical didactic design adopted for the Engineering courses. In Engineering Teaching, the PBL is a popular approach that is being implemented in universities around the world to form versatile engineers (Noordin et al. 2011). This type of learning, as defined by Powell & Weenk (2003), is a methodology that emphasizes teamwork in solving interdisciplinary problems that combine theory and practice. The objective is to create a solution or product from a real situation related to a future professional context.

These authors indicated that the main features of this methodology, known as Project Led Education (PLE) emphasize student learning and the students' active role in this process, in the interests of developing not only technical skills but also soft skills. The methodology is to provide conditions for students to develop these skills, integrating and applying knowledge from different disciplines in a common project which plays a central role in their own learning. This process is focused on the following objectives:

- Promote student-centered learning;
- Foster teamwork;
- Develop initiative and creativity;
- Develop the capacity to communicate;
- Develop critical thinking skills;
- Relate interdisciplinary content in an integrated manner.

The structure of the curriculum was designed for competencies to be developed for each discipline but always in an interdisciplinary and transdisciplinary manner. Every semester (Brazilian programs take 10 semesters) there is a project covering two or more disciplines with clearly-defined contributions to project objectives. Such purposes include the development of both soft and hard skills, and the design of these projects follows an inverse intensity gradient between these skills, as shown in Figure 2. Thus, in the first semesters there is a greater emphasis on soft skills while the second part focuses on hard skills.

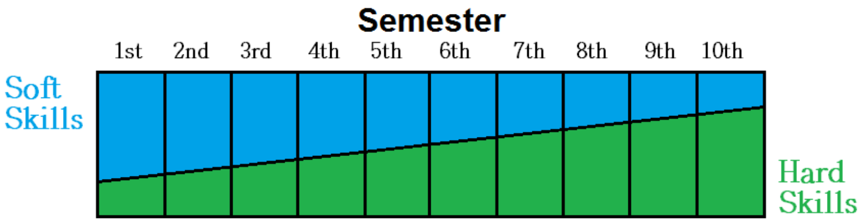

Figure 2. Hard and Soft Skills Gradient

As an example, in the fourth semester of the Industrial Engineering Program students were given a project to design and build a catapult. With stipulated maximum dimensional requirements, students would design and build a catapult to consider at least three launch parameters. They would then, using design of experiment (DOE) techniques, find the best combination of the input variables and then reproduce the optimal release. A competition for greatest horizontal reach was created among the teams. A matrix including each discipline's contribution toward the project was developed with professors acting as coaches focused on the objectives of the project. Partial and final reports were required and the evaluation criteria considered factors such as fulfillment of proposed objectives, structure, reasoning, conceptual rigor, capacity for reflection and critical analysis, meeting deadlines for delivery and collection of prototype data. Also considered in project evaluation were the project presentations (communication and creativity) and the prototype performance (relevance, correctness and quality of the solution). Figure 3 and Figure 4 show details of the project and launch.

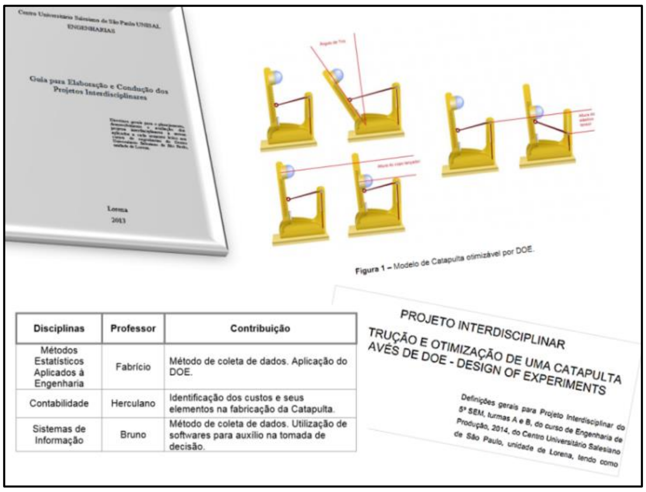

Figure 3. Design a catapult and use of DOE

Figure 4. Flagrant launch catapults

4 Fluid mechanics course: no lecture, no assessment

For the structuring this new approach it sought procedures suitable for use in the course, considering the characteristics of its contents, the intended instructional objectives, the course of history and the available infrastructure. Although not consensual alternative teaching learning process for the acquisition of technical knowledge, strengthening members skills and attitudes of the professional profile, some possibilities are found in the literature, associated with different strategies (Lopez, 2007; Felder & Brent, 2003) that provide a basic reference for structuring actions.

The first experience in delivering a discipline exclusively via PBL (Project Based Learning) occurred with fourth semester engineering students in the Fluid Mechanics class. It took nearly a year to prepare and format the course; all meetings, activities and projects were prepared and tested in a pilot. The conceptual, procedural and attitudinal objectives of the course were developed from a contribution matrix with each proposed activity. Throughout the semester, the forty class hours were divided into twenty meetings, one per week, and about forty hours outside of class were added.

The dynamic that was developed was essentially as follows: students were "challenged" to perform an activity prior to class: it could be reading something, but most of the time it was a practical task. For example, the challenge could be the calculation of a specific force in a submerged surface or a problem related to software that simulates Reynolds number. The students would work in teams outside of class although feedback would occur individually through the online system. Then, in class, in a period of around 20 minutes, students would individually answer a given set of problems and issues. Afterwards the same problems and issues were presented to the teams and, this time, working towards consensus, they would seek the correct alternative from the starting point of their individual opinions. This is where the learning actually happens, when students explain their opinions to each other.

At the same time as the above activities, all course content was divided into three structural axes that generated three projects that were presented formally in writing evaluated by professors and especially-invited industry professionals. No specific requirement was made about the projects, except for their adherence to the principles of the related axes. This flexibly resulted in a very gratifying outcome: each project is an auspicious surprise. In fact learning of a concept happens as a consequence of the chosen project, and not the other way around. So it's simple: if the student cannot learn the concept, he cannot complete the project.

There were no lectures for this class. Sometimes the professor would address the class to inform them about objectives or provide an overview. This never took more than ten minutes and only occurred from time to time. The entire course was developed to be performed in laboratories in the "Design Thinking" environment described above in this article. The grading is done in a continuing process that promotes learning. The grade for each student is a combination of their individual and group performance on course activities. Throughout the above process, the professor was available to provide guidance and answer questions. Rather than "teaching", the professor is more of a coach.

A preliminary analysis of the results can be performed based on the three critical components associated with PBL (Masek & Yamin, 2010) and are the format and the structure of the placed issues (Sockalingam, 2010), the role of guardians (Wee et al., 2001) and assessment strategies (Olds et al., 2005).

Although the analysis of the problems appropriate for PBL strategy involves some complexity, it can be used consensual points of literature pointing to features like authentic, complex, open, theme and possible solution, within the capacity of students (Wee, 2004).

5 Teaching-Learning Evaluation

The project, described in the previous item, involved in monitoring of all stages of knowledge building in a continuous and formative assessment process. Thus, the assessment becomes part of the teaching-learning process that allows knowing the result of the didactic actions in order to improve them (McNabola, 2013).

A method in five steps, based on Schell et al (2014) and Vasconcelos (2003) has been implemented.

In the first step, an assessment of prior knowledge of the student was carried out. That is, a diagnostic evaluation about the concepts and intended previous skills for the design and/or each of its steps. In this case, objective questions about the concepts, tasks, and exercises relating to the desirable concepts and skills were applied for the purpose of diagnostic. In some phases of the project, the choice was small practical experiments or perceptions of everyday life to which students should answer certain questions in order to identify their prior knowledge of the subject.

In the second, the aim has passed to be the evaluation of student organization. According Vasconcelos (2003) it is necessary that the teacher guide the student to arrange your own time studies and your search so that they can socialize and participate effectively in the project. For Schell et al (2013) is necessary encourage the students to make the proper connections between the concepts and ideas worked in project execution? At this stage, the assessment tool can show the teacher whether - or not - to review the case. As a practical question, for example, is challenging students to answer a trouble situation where they can go building mind maps that the project and / or activity requires as needed for the transposition of prior knowledge (trivial) for deeper knowledge.

In the third stage, the evaluation focused if student is developing competences that enable to deepen the knowledge. For Schell et al (2013) it is the sophistication of the principles and basic concepts. For example, a dialogue between the student and his colleague, or the formulation of questions related to the project and/or activity that not yet worked or others doubts and problems.

Following, the fourth step is a self-evaluation. At this stage the aim is to awaken in students the need to evaluate what they are doing and how is significant and important for their education. The students might be asked to answer what they have learned and that has not yet achieved. For example, may be asked to answer the question "what more do you want to know about the subject?"

Finally, the fifth and last step, addressed the effectiveness of learning. This refers to the work done by the group in which it is expected that the student is able to transpose the knowledge beyond the concepts learned and validated to everyday practices and challenges. The instrument sought the questioning in a context where it is necessary a pertinent response to the concepts previously defined in the project. It is expected realize the evolution and assimilation of competences in each discipline and interdisciplinary way.

This approach enables the learning of required interaction for teamwork, both among its members how the environment where they live, strengthening skills, the acquisition of technical expertise, the development of attitudes and behaviours that enable them to cope with the environments work on completion of studies (Noordin et al, 2011).

6 Conclusion

Active teaching methodologies have been employed for decades in various parts of the world, and the results have been published. In Brazil, these methods have not been systematically used and there has little about the Brazilian experience in the literature.

Despite the importance of PBL in engineering education, when considering the amount of engineering courses in Brazil, it appears that the number of studies involving this methodology is virtually meaningless, because these initiatives are very recent and limited to specific disciplines within the engineering course lasting at least five years (Campos et al. 2011)

The re-engineering of programs, even if made easier by starting from scratch, is an ambitious project and UNISAL seeks to be in the forefront of this educational process, working in a structured and evolutionary way, covering programs in many disciplines. The application of any active method for the first time requires a coherent planning of activities in order to prepare both the materials and the means that will be used in the teaching process, but, above all, guide the teacher in the dynamics of learning.

Litzinger et al. (2011) that summarises instructional practice for successful development of expertise in engineering education presents the following argument in the conclusion: “We believe that the use of a systematic curriculum design process can assist in overcoming such barriers and greatly increase the chances of successful curriculum-level integration of effective learning experiences”.

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University-Business cooperation to enhance Innovation and Entrepreneurship using PBLs

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Abstract

This paper presents the approach followed at Mondragon University (MU) to boost entrepreneurship, to enhance innovation by means of collaboration with companies and to transfer R&D results from university to industry and Society using active learning techniques. The mechanisms used are channelled through contests and implemented in Problem Oriented Project Based Learning (onwards PoPBL or PBLs), training projects and final grade projects. The main challenge is how to transform the results of those activities and technological prototypes created by students into new products, services or businesses that revert into companies or suppose the launching of new start-ups. Another challenge is how to encourage and facilitate the collaboration of different agents (students, researchers, public and private organizations, companies and technological centres, etc.) in such innovation processes. The approach consists of 1) articulating an entrepreneurship network of partners based on the participation from different business units at University and external agents (companies, research centres and public administration) and 2) providing a systematic innovation process that proposes events and activities to boost collaboration. MU designs an annual contest to create the network and to implement the process, and defines for each contest the collaboration among agents, the expected results, the selection criteria and other constraints. Students present their work in several stages (deliverables) and develop their ideas in PBLs and projects. A platform where collaborative innovation contests are registered and managed supports the whole process and uses Key performance indicators (KPI) to measure the process, the level of participation and the obtained results. The work presented in this article is based on the pilot experiences conducted during the last 4 years in MU, specifically for the Bachelor's Degree in Computer Engineering and Telecommunications Systems Engineering and Master's Degree in Embedded Systems in the Faculty of Engineering of MU (onwards, ICT degrees). The experience has been included as one of the use cases in the ACCELERATE project, A Platform for the Acceleration of go-to market in the ICT industry. ACCELERATE is an ITEA2 - Information Technology for European Advancement project, which main objective is to research in methodologies, tools, innovative ICT Technologies to support transfer of acceleration knowledge on a massive scale in Europe. The article describes the measures taken at university during this time: the definition of the approach as one of the goals into the University's Management Plan, included University-Business collaboration and the definition of an entrepreneurship itinerary for ICT degrees. The article includes preliminary results in terms of number of start-ups and innovation projects that had continued developing and the evolution of the participation in university contests. Finally, the article presents conclusions extracted from the implementation of the approach, placing special attention in identifying the challenges preventing an agile transferring of the results and the acceleration measures proposed to speed-up and improve this process.

Keywords: engineering education; university-business cooperation; entrepreneur skill in PBL; innovation;

1 Introduction

Innovation is extremely important for the growth strategy of most enterprises (Capozzi, Gregg & Howe, 2010). With the rise of emerging economies, businesses are entering an era of extreme competition where the only way to survive is to innovate. Many companies and especially Small and Medium Enterprises (SMEs) have problems applying innovation processes, because of the lack of resources, appropriated tools or innovation culture. Without innovation, those enterprises cannot grow on their businesses and their competitors take advantage of that weakness. Innovation allows enterprises to compete and evolve efficiently.

Collaboration between many agents is critical to improve the innovation process, especially among the three main institutional spheres of industry, academia and government (Etzkowitz, H., Webster A., Gebhardt C., Cantisano Terra B.R., 2000). Moreover, universities are catalysts for the enhancement of employment opportunities for local industry, especially with regional and national governments viewing the high technology and knowledge-based sectors as a crucial source of direct and indirect employment opportunities in the future.

Getting more in depth, Universities contribute to the R&D capability of an economy in different ways, including: the creation of new knowledge from basic research, the production of specialized human capital, the technology transfer from academia to industry and the territorial development, through the promotion and management of projects of territorial innovation (Lazzeroni, M. and A. Piccaluga, 2003).

University has been adapting its mission to the needs of the economic and social situation, adding to the traditional task of teaching, others activities as: research, technology transfer from universities to industry, the need to develop more "rapid" linkages between science, technology and utilization, and finally, entrepreneurial orientation and spinoff performance (O'Shea, R., et al., Allen T.J., Chevalier A., Roche F., 2005). Universities are playing a major role in regional innovation and economic growth (Etzkowitz, H., 2003) and can be a key provider of new technologies and business ventures.

MU has followed these principles since its origins. One of the main characteristics of MU is its close and permanent relationship with the business world, which enables the institution to outline the educational offer by adapting it to the needs of companies, organisations and society. MU has his own educational project, which is based on innovative active learning methodologies. In 2002, The Problem Oriented Project Based Learning methodology was launched for the first time in all its engineering degrees.

MU is part of Mondragon Corporation (onwards, Mondragon, http://www.mondragon-corporation.com/eng/) the top Basque business group, seventh in Spain and a global benchmark for cooperativism. With 256 sites, 94 foreign production plants and 9 corporate offices, this business group works in the areas of Industry, Finance, Distribution and Knowledge. Innovation is one of the distinguishing features of Mondragon Corporation, which has established a new corporate innovation model called M4FUTURE (http://www.mondragon-corporation.com/eng/corporate-responsibility/innovation-model/).

Among different innovation activities, Mondragon has constructed a structure called The Business Acceleration Centre of Mondragon (onwards, Mondragon BAC, http://www.iseamcc.net/isea/business-acceleration-center) to promote the launching processes of new enterprise initiatives in the advance services sector. Mondragon BAC has deployed the social Network Elkarbide (http://www.elkarbide.com/) to articulate the collective knowledge and share experiences inside the Corporation.

MU participates actively in collaborative research and Transfer actions, with companies inside and outside Mondragon in a University-Business cooperation context. These collaborative research agreements are growing every year, due to defined roadmaps and the connection stablished around the PhD, Master and graduate students, and lecturers and researchers. Nevertheless, the creation of new start-ups, new businesses for companies, new products and services that revert into companies are not as successful as expected. To revert that situation and to grow the capacity to innovate and build new business, MU has defined an approach, with the collaboration of BAC Mondragon. The main motivation of these initiatives (presented in this paper) is to link student internal projects with company projects and to give them continuity through final year projects. In others words, transform the results of those activities (methodologies and technological prototypes created by students) into new products, services or businesses that revert into companies.

Since 2007, an annual contest (http://www.mondragon.edu/es/actualidad/ novedades/destacados/ekiten-formulario/ekiten-lehiaketa-cas) is designed for students to enhance innovation and offers them the opportunity of take advantage of their PBL projects to presents their own innovative ideas.

Others challenges are how grow the quality of this participation, how to encourage and facilitate the participation and collaboration in such innovation processes of different agents (students, researchers, public and private organizations, companies and technological centres, etc.). Nevertheless, these processes of transference and creation of spin-offs are not easy tasks and many challenges must be overcome. In order to facilitate the involvement of companies, Mondragon BAC is a core collaborator of the experience. Other collaborator is Saiolan (http://www.saiolan.com/), the entrepreneurship centre of Mondragon.

Every year, improvements are included into the approach. Among these improvements, the definition of an entrepreneurship itinerary for Bachelor degrees or the establishment of collaboration working groups between different Masters Specialities in the Faculty of Engineering. The reinforcement between researchers, their R&D collaborative network with this itinerary and the building of a good accompaniment for student during the carrier or after this is another important challenge, to drive the entrepreneurship straightforward and accelerate this process.

Since 2007, MU has been involved in many research projects to identify how to improve Innovation and Entrepreneurship. In 2013, the approach presented in this paper was included as a use case in the ITEA2 project called ACCELERATE, A Platform for the Acceleration of go-to market in the ICT industry. The objective is to apply the methodologies and tools to include into the approach. KPIs identified in ACCELERATE are also used to measure the impact of including those improvements. One of these tools is Innoweb (http://innoweb.mondragon.edu) (Perez, A., Larrinaga, F., Lizarralde, O., Santos, I., INNOWEB: Gathering the context information of innovation processes with a collaborative social network platform, 2013). Innoweb is an idea management system (IMS) used to support several stages of the innovation process. The tool has been used for the last 3 years. The collaborative innovation contests are registered and managed, and many Key performance indicators (KPI) are included to measure the process, the level of participation and the obtained results.

This article describes the experiences conducted during the last 4 years and describes the measures taken at university during this time. The structure of the article is as follows; a description of the approach is presented first. The following sections present the description of the pilot experiences; starting with the design of the experience and following with the description of how the experience was developed. Innowave platform is presented next. Preliminary results are presented in terms of number of start-ups and innovation projects that had continued developing and the evolution of the participation in university contests. Finally, conclusions extracted from the implementation of the approach are presented. Special attention is placed in identifying the challenges preventing an agile transferring of the results and the acceleration measures proposed to speed-up and improve this process.

2 MU's Innovation approach

The approach summarized in Figure 1 is designed considering a process with several main phases: Competition and Workshop, mechanisms and PopBL, and diffusion and results. The approach follows a methodology. All of these elements are described with more detail in the following lines: 1)competition and workshop; 2)Mechanism and PoPBLs , and 3)Diffusion, Results, Awards giving ceremony and exhibitions.

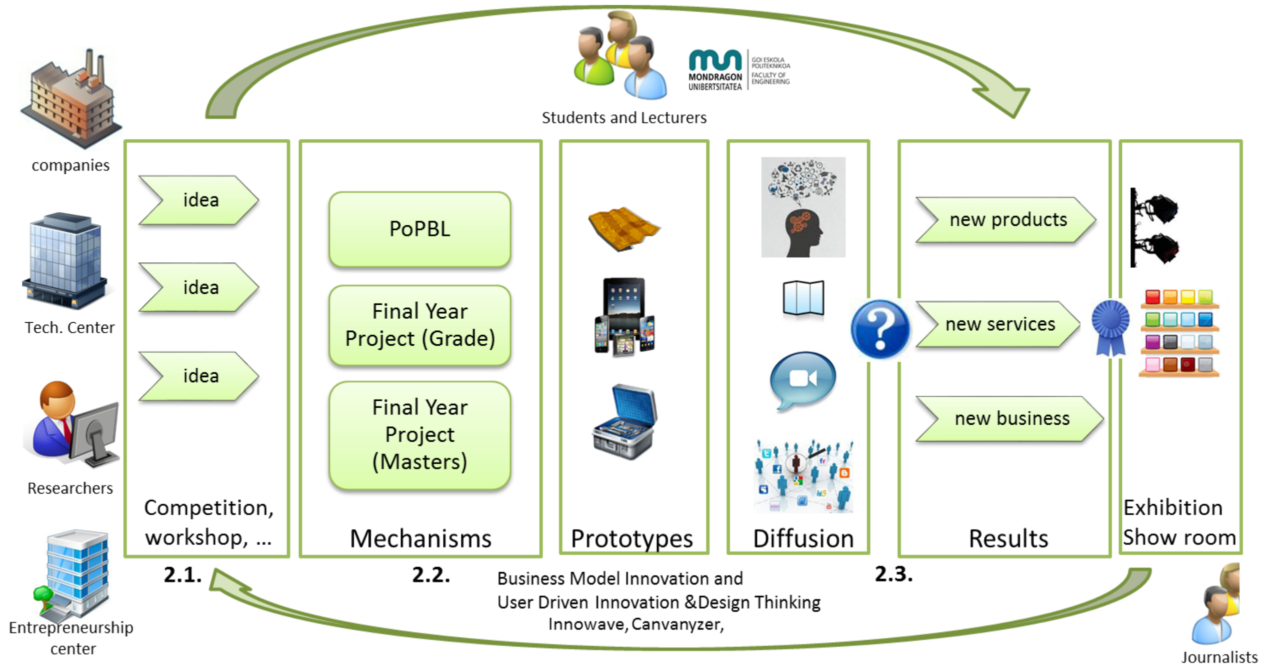

Figure 1: the MU's innovation approach

2.1 Competition and Workshop.

The first phase takes into account two main aspects. First, the agreement with the public and private organization network to participate on the annual contest of MU. This agreement includes the selection of the scope and the definition of the challenge for each annual MU contest. The topic selected is usually aligned with one of the societal challenges defined for The European Commission. MU's academic coordinators take part in the selection of the challenge, which is communicated within all degree workgroups. These workgroups decide to participate or not in the contest and design PBL projects aligned with the challenge.

Another important aspect is the sponsor of the contest. They are usually three awards for each subject and sponsor (1000€ for the first winner and 500€ for the second and third). MU defines the contest conditions, milestones and expected deliverables, selection committee formed by external experts and selection criteria: level of innovation, definition, maturity and economic feasibility of the idea, level of alignment with strategy and topics, confluence and leverage with the capacities in the corporation, the level of interdisciplinary and the popular vote (social web). These conditions are registered in Innoweb platform (social web) as a wave or specific contest. Finally, the agenda and the compromises to reinforce the University-Business collaboration are established: participation in the workshop, selection of the committee of the contest and many different diffusion actions, included the participation into the award given ceremony.

Second, a Workshop is organized. For the successful development of the workshop, the involvement of research groups is essential. Counting on companies that collaborate with those research groups is also of major importance. This workshop is the first contact with companies for the students. They heard about the characteristics of the challenge they need to aboard and the current business problems that companies are facing, and start thinking about ideas that should be turn into projects. The workshop is structured in three steps: the warming-up, the working step and the conclusions and closing. Different dynamics and techniques are worked out; brainstorming for idea generation, selection matrix is for idea prioritization and business model Canvas.

2.2 Mechanism and PoPBLs.

This second phase is structured in three milestones, where specific objectives had to be achieved. The workgroup of each degree in The Faculty of Engineering need to define these milestones, according to the specialization and the academic response needed. At the same time, each milestone is followed by a feedback session, where teachers, experts, researchers, tutors and participating organizations tell the students about the work they had developed so far. The methodology followed by students to design their products and prototypes is user driven innovation & design thinking (http://dbz.mondragon.edu/es/imagenes/metodologia-dbz). This is an iterative methodology based on the use of many different tools. The result obtained after this phase is a Business plan and a prototype, developed in an incremental way. During the whole project, they work in three dimensions: a global idea for a product/service (this is important for the business plan), the prototype that they have to build as a demonstrator and many deliverables according to the specialization chosen.

After the first milestone, the idea is presented, justifying their innovative dimension, together with the first generic business plan, the architecture of the project and a project plan, considering the milestones and describing what type of a prototype is expected.

For the second milestone, the objective is the same but the students have spent two or three months maturing the idea, and they have analysed and selected the technological alternative to build the prototype.

For the last milestone, they present the idea, the business plan and the prototype. They work in a promotional video and a poster. They finish the process with an elevator pitching presentation and an executive summary for the participating organizations, where they resume the whole project.

In all these milestones, the academic competences are evaluated. Sometimes in a direct way with teachers involved and others through stablished tests. Open presentations are organized and companies participate and give their feedback to students. In addition, during the whole period, students can contact experts, with the supervision of the tutor, have coaching sessions with tutors and can ask for resources for the project. In some cases, the communication with industry is direct.

Students use the Innowave platform to introduce their ideas/proposals (description, title, outcome expected, issues addressed, type of innovation and objective market) for the 1st phase of the contest, and more detail, video, poster and memory for the second.

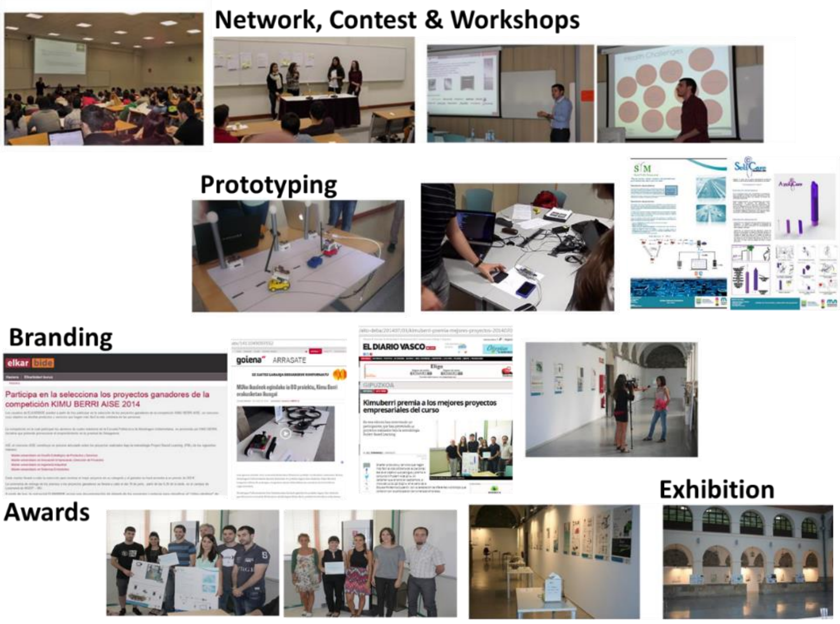

Figure 2: Some pictures of Workshop and deliverables.

Experts rate and select best ideas in each phase of the contest. The objective for the 1st phase is to pass to the second one. The goal for the 2nd phase is to select the final winners.

Figure 2 presents several pictures from the different phases of the process. 1) Students and experts participating in workshops; 2) Some prototypes and posters describing developed ideas, result of PoPBLs and final products for the contests; 3) Diffusion actions in social networks, digital newspapers to present the work done for students: videos, prototypes and interviews and finally, 4) awards giving ceremonies and exhibition with posters, prototypes and projections of videos.

2.3 Diffusion, results, awards giving ceremony and exhibitions.

All the videos are published in Elkarbide, the Mondragon BAC's social web. They are voted by the users of this social network, mainly people from companies in Mondragon Corporation. The resultant ranking is considered as the popular vote and it is one of the criteria for the selection of ideas in the annual contest.

Once the winners are known, an award giving ceremony is organized. Winners in each category receive a price from companies' representatives, public administration and sponsors. Mondragon BAC participates in the act. Journalists are invited and publish different articles and reports in local and regional newspapers.

Finally, open doors days are organized where students present their work. Prototypes and posters are exhibited in different public spaces for several weeks.

2.4 Methodology

Improvements are introduced every year in the approach and in the tools employed to support it. The agreed methodology to achieve that is based on an incremental development cycle. The experience collected in each cycle will help improve the next one. A set of indicators are set up in order to evaluate the result and the success of the project. The results and conclusions obtained in one cycle can generate new improvements for the next one.

Some of these actions are related to the early phases of the approach, which complete the implemented process. This process is supported by The Innoweb platform where collaborative innovation contests are registered and managed. Collecting that information is essential to reproduce the conditions and the context where successful ideas take place.

Others actions included during different cycles are related the University-Business collaboration. Actions related the Mondragon BAC's collaboration are considered here.

2.4.1 The platform Innoweb

On the early stages of innovation processes, we can find the idea generation stage. Many idea management systems (IMS) tools can be found on the market but most of them are idea centred but hardly collect information about the context, the conditions on which those ideas have been gathered.

The Innoweb platform is the result of the research team of Web engineering in MU (http://www.mondragon.edu/en/phs/research/research-teams/software-engineering) and represents an IMS focused on the innovation context, where this kind of information is gathered: information such as the type of contest where the idea was conceived, the actions taken during the different stages, the contributors on an idea or the timing between stages.

Innowave tool developed supports the whole process designed into the MU's approach: gather ideas, analyse and evaluate them and select them, serves as an idea repository and offers dashboards to measure some KPIs.

2.4.2 University-Business collaboration.

In the approach followed at MU to enhance Innovation and Entrepreneurship using PBLs, the University-Business collaboration is essential, since it has been considered from the very beginning of the project. Evidences of this interaction are present from the very beginning of the process. Some of these are: the construction of an ecosystem form by companies and technological centres, public agencies, students, researchers,…; the definition of the topic by that ecosystem and the sponsorship of the contest; the compromise of the BAC Mondragon and the Elkarbide social network to attract organizations, the workshop, where students and professionals shared table to identify possible business ideas; the active participation of the committed organizations in the public presentations, giving feedback to the projects teams and evaluating the quality of the work done or voting the videos and finally, contributing with the diffusion of ideas.

3 Results

The results from the different contest in MU are summarised in Table 1. Some of these values are obtained from the Innoweb platform:

- Number of ideas has increased although Promoted ideas and Spin-offs maintain. All the spin-offs are created by students from the Bachelor's Degree in Computer Engineering and Telecommunications Systems Engineering (ICT degrees).
- Four of the six promoted ideas in 2013-14 are created by students from ICT degrees also. Others are from the Master's Degree on Strategic design of Products and Services. Promoted ideas represent ideas where students have been hired by companies to further develop on the prototype or the technology.
- The participation has grown in general and specially in the ICT degrees. The 105 ideas for the 2013-14 include 14 from students from Latin America, who participate for the first time.
- The number of experts and evaluators involved has also grown. The collaboration with the network (company and public administration).
- The number of events (workshops, brainstorming sessions, speeches,…) has increased. Apparently, there is a relation between the organisation of these events and the amount of ideas placed by the students.
- The average grade of ideas has improved. For the last two years, the contest is designed considering two milestones. The quality of ideas in this 2nd phase is better, and by consequence, the average grade is better.

- Every year one group from the ICT degrees has achieved an award.
- Students from the Master's Degree in Business Innovation and Project Management obtained some awards. This groups follows a slightly approach described in (Markuerkiaga L, Errasti N., Igartua J.I., 2013). The results of this pilot experience are described as satisfactory in many levels: the academic result have increased a 25%, the feedback obtained from the companies has been highly positive and tutors and experts were impressed by the results obtained and the commitment of the students.
- Students from the Master's Degree on Strategic Design of Products and Services are very active too, but they usually design their PBLs to work in a closed ecosystem with specific clients. The agreement of confidentiality stops their participation in the contest. Two of these projects in 2013-14 have become promoted ideas to continue developing among Final year project.

Table 1: KPIs of the contest during the last 4 years (Total number MU/ only number of ICT degrees)

Outcome	2010-11	2011-12	2012-13	2013-14
Ideas	10/3	27/4	49/4	91+14=105/8
Promoted ideas	3/3	2/2	3/3	6/4
Spin offs	0	1/1	1/1	1/1
Groups	10/3	27/4	46/4	98/8
Participants	40/12	92/14	15/14	240/25
Experts	10	10	10	14
Evaluators	9	9	9	10
Events	11	16	24	24
Avg. grade of ideas	-	3,76	4,77	5,9

4 Conclusions and future lines

The main conclusion is that the approach is well designed, and the results obtained go in the good direction. Number of ideas, promoted ideas, spin offs are increased and experiences continue, after the integration of an entrepreneurship itinerary for Bachelor's and Master's degrees.

Furthermore, the University Business Cooperation is essential. A "strong" network (company and public administration) and the involvement of stakeholders and beneficiaries is a key factor for success.

Involvement from the University researchers and research groups in the early stages (ideation) and involvement of company /public administration recruitment /involvement is very important also, especially in the prototyping and the development process of the product/service.

Economic factors also affect ideas promoted and spin-offs. Other new mechanisms need to be checked. For example, offering grants for the projects until the end of studies, the final year projects and after the end of the degrees. Companies are focused on their business and have few resources for new businesses, but University with the BAC Mondragon is working in this direction. For example the Etorkizuna Elkarrekin Eraikiz (E3!), activated in January 2015, is offering a grant to work in an innovative project. Perhaps in the future crowdfunding strategies need to be explored.

Interdisciplinary projects where students from different specialities work together in the same project is another possibility worth exploring. Some Master's Degree are naturally interdisciplinary, because of the previous Bachelor's Degree in origin, but the establishment of collaboration work teams between different Masters Specialities in the Faculty of Engineering is desirable.

A lack of entrepreneurship culture among students and other skills are detected, especially in technological degrees. Formative sessions during the different stages of the process to boost entrepreneurship among students (knowledge pills) need to be included in the programme. A new collaboration line has been opened with Saiolan Entrepreneur Centre.

An agreement to stablish clearly the intellectual property of the ideas/prototypes is another aspect to work.

Finally, the methodologies, tools and good practises detected in the ACCELERATE project should be applied in MU's approach. For example, the idea of evaluating other lead users presence and participation is desirable. This is open the network of others stakeholders during a "market phase". The platform Innoweb must be adapted to other social networks where ideas and projects can be shared. Another interesting proposal withdrawn from ACCELERATE is the idea of creating "Idea Markets" where previous ideas are "sold" to companies and new "ideators" or use accelerate tools like Deckmind (http://invite.deckmind.com/).

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Iron Range Engineering PBL Experience

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Abstract

A new PBL model started in 2010 in Minnesota, United States. The PBL model is upper-division (the last two years of four-year bachelor's of engineering degree). Entering students are graduates of Minnesota's community colleges. The Aalborg PBL model served as an inspiration for the program's development. Unique attributes of the program include industry clients, semester-long projects, emphasis on development of self-regulated learning abilities, dedicated project rooms, technical competence learned in one-credit, small (3-4 student) groups with one academic staff called learning competencies, and an emphasis on continuous improvement. The program has earned ABET accreditation. Seventy-five students have graduated and are employed as engineering professionals. The paper will discuss developmental evolution of the program, the current learning model, and will analyze results of satisfaction surveys of graduates and their employers. A case study was employed to describe the development and attributes of the PBL model. The satisfaction survey is a quantitative instrument based on the expected outcomes of the engineering education and is providing contextual comparison with non-PBL graduates.

Keywords: project-based learning; self-directed learning; professional skill development; continuous improvement; industry component.

1 Introduction

The Iron Range Engineering program is a new PBL curriculum in Minnesota in the United States. This curriculum was initially adapted from the Aalborg University PBL model in Denmark. The program began development in 2009 and implementation in 2010. Following are descriptions of the model, its development, and results of satisfaction from the graduates of the program as well as their employers.

2 Developmental Evolution

The developmental evolution has two parts: the history leading up to implementation of the model and the evolution of the model from its first day in January 2010 to its current form in 2015.

2.1 History of model

The prime developers of the PBL model were engineering faculty members at a community college that provided students with the first two years of an engineering bachelor's. Students would then transfer to regional universities to complete the last two years of a bachelor's degree. The faculty members had implemented active learning into their teaching and found that when students transferred to the final two years where there was no active learning, they reported dissatisfaction with the final two-year experience. Further, the engineering faculty members became more and more dissatisfied with their perception that the entire four-year engineering experience for students developed a skill set that was misaligned with the competences that were expected of new graduates when they entered the engineering workforce. In 1997, ABET first published the ABET 2000 criteria (http://www.abet.org/History/). The engineering faculty found new hope. The student outcomes presented by ABET were much more aligned with the needs of engineering employers (http://www.abet.org/eac-criteria-2014-2015/). However, six years after the adoption of the ABET criteria, these engineering faculty members sensed no change in the alignment of the student engineering experience.

"The initial idea germinated in 2003 as these circumstances collided: continued and accelerated success of the Itasca Community College (ICC) engineering program where the developers taught, frustration by ICC graduates as they transferred into systems whose focus was not on educating undergraduates, conversations by ICC faculty with many faculty from engineering universities who were frustrated about not being able to focus on undergraduate education, and the large-scale layoffs in a local industry causing an economic downturn for this region. At first, the idea was considered an unrealistic dream…sort of a "what would we do if we won the huge Powerball jackpot?". It was a conversation with a community leader that turned the idea from a pipe-dream to something that should be considered more realistically. She encouraged us to pursue this dream. Over the course of the next two years, serious conversations took place between ICC faculty, community members, and people from academia. It was decided that a gathering of these constituents should take place to verify the idea and, if verified, chart a future course. Thus, a local foundation funded a planning conference in the summer of 2005 at which leading engineering educators from around the country met to discuss the feasibility of such an idea. This was followed by positive and encouraging discussions with local and regional community leaders." (Winkel, 2005)

From 2005 to 2009, the original faculty members from the community college and the partners from engineering education around the U.S. continued to refine the idea and seek funding. In April 2009, a regional organization funded the program's startup (Cole, 2012). An advisory board was formed from among the leaders in U.S. engineering education. Sheri Sheppard, Tom Litzinger, Denny Davis, Jeff Froyd, and Edwin Jones began guiding the program's development. Their advice led to program directors visiting Anette Kolmos at Aalborg University. In January 2010, the Iron Range Engineering program, a collaboration between Itasca Community College and a degree-granting engineering college at Minnesota State University, Mankato, began delivering the IRE PBL model, an adaptation of the Aalborg model (Johnson and Ulseth, 2014).

2.2 Implementation

Two parallel levels of implementation took place. First, PBL as a curriculum is not widespread in the U.S. The university systems and mentalities were not well prepared for the change in educational practices required for implementing this PBL model. Allendoerfer (University of Washington) and Karlin (South Dakota School of Mines and Technology) undertook an NSF sponsored study of the change management activities that occurred during this start-up phase. Their paper, Leading Large-Scale Change in an Engineering Program (Allendoerfer et al., unpublished) has been submitted to the 2015 annual ASEE conference. Initial findings show the barriers to change to include credentialing issues, ownership, culture clash, and resistance to change. The empowering factors to change were the "importance of having champions at all levels, creating new boxes for the new program, and having translators positioned at key bridging points" (Allendoerfer et al., unpublished).

The second level of implementation was the evolution of the program as feedback from each semester showed which attributes of the model were working and which were not. Early in the implementation, a model of continuous improvement was adopted by the program leaders (Ulseth and Johnson, 2014). In this model, inputs are actively sought from constituents each semester. These constituents are current students, industry partners, visiting engineering education experts (at least one group per semester), and academic staff. At the end of each semester, "Summit 1" is held where the academic staff members organize, categorize, and rank all received inputs. Between summits, program leaders turn the inputted ideas into action plans for implementation. "Summit 2" is held one week before the beginning of the new semester. All action plans are discussed and modified to best allow implementation in the new semester. This process has resulted in great change in the student learning experience. Particular areas of change have been team composition, development of different student competencies, environmental factors, inclusivity and gender equity, scope of industrial projects, and emphases in the engineering design process. The results of this process have been a smooth ABET accreditation process, high levels of ownership in the program by faculty and student groups, low levels of apathy by the faculty and student groups, and a vibrant curriculum that is constantly improving (Ulseth and Johnson, 2014; Bates and Ulseth, 2013).

3 PBL Model

The program can be communicated by considering three different domains of learning: design, professional, and technical.

3.1 Design

Central to all learning in this model is a semester-long design project. Projects come from either real industry problems that need solution (80%) or entrepreneurial ideas of students (20%). An engineering design process is used to guide students from problem scoping through solution realization.

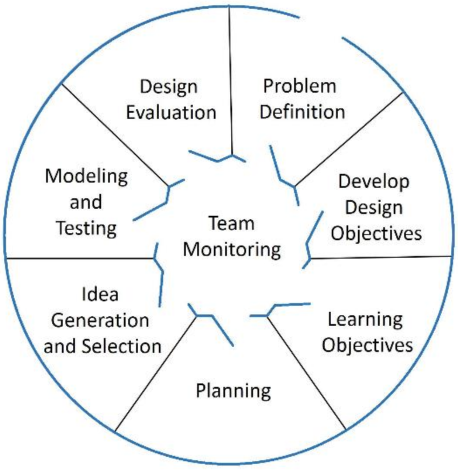

Figure 1: Iron Range Engineering Design Process

An engineer on the academic staff is the project facilitator, who scaffolds student development through guidance and coaching. Students develop their teams, their approaches to project management, their acquisition of research and technical knowledge, their professional responsibilities, and their approaches to written and verbal technical presentation. Through close interaction with their industrial client, the student teams develop design objectives, generate concepts, model and test solutions, and select final designs. Three times each semester, the teams defend their work at formal design reviews, present their project status to clients, and submit formal design documentation.

Student design team rooms are modeled after the group rooms at Aalborg University (http://www.en.aau.dk/education/problem-based-learning/group-work/). The purpose is to have a physical space where students have their own office; a place where the team has access 24 hours per day, 7 days per week to work on their design project or their individual learning. Figure 2 is a photo of an IRE project room, as well as other design team learning spaces. Weekly design reviews take place in the room. The walls are filled with whiteboards and project oriented posters. Each student has his or her own desk and bookshelf. This proximity provides for substantial team interaction, which empowers team development and project advancement.

Figure 2: Design team learning spaces

3.2 Professional learning

The students emulate the program's model of continuous improvement, turning it into their own development as professionals (Habibi, Ulseth, and Lillesve, 2014). Upon their entrance into the program, with the assistance of an academic staff member, the students evaluate themselves on a continuum of novice to expert in each of nine different professionalism areas: written communication, presentation communication, leadership, learning about learning, professional responsibility, inclusivity, ethical practice, teamwork, and knowledge of contemporary issues. Each semester, students attend workshops run by experts in these fields to acquire new knowledge and strategies. They then implement the knowledge and strategies into their daily work on their projects. For example, leading their peers, performing on their team, writing their technical reports, presenting to their clients, dressing appropriately, treating others with respect, etc. They receive continuous feedback from their peers and their instructors on their performance and development in these areas.

At the end of each semester, the students create a professional development plan (PDP) document (Habibi, Ulseth, and Lillesve, 2014). This document has nine chapters, one for each of the development areas. Each chapter details learning in the area that occurred during the semester, a reflection on how well previous goals were met, a current evaluation of the student's perceived level of performance, goals to be met by the end of the next semester, and an action plan putting forth detailed steps to be taken in an effort to achieve the goals. These chapters of the PDP highlight development in six of the eleven ABET student outcomes (http://www.abet.org/eac-criteria-2015-2016/) that the original developers initially felt were not being adequately addressed in engineering student learning experiences in traditional engineering programs.

3.3 Technical learning

Students have control over which competencies they take each semester with guidance from academic staff. As students decide which competencies to complete each semester, they have two objectives they are trying to meet. The objectives are, first, choosing learning that benefits their semester project and, secondly, choosing learning that is aligned with their desired engineering field. Most often there is overlap between these objectives. Most student projects align with their desired depth emphases. The courses are delivered in 2 half-semester periods called "blocks". At the beginning of the semester, students decide which 4 competencies to take for the first block. Then, at mid-semester, they select 4 competencies for the second block. The goals of this system are to provide flexibility and student ownership. By choosing what to take, when it makes the most sense for the project, the students have the opportunity to have high levels of contextual relevance.

The first day of each competency is called "syllabus signing day". In this conversation, the students and the instructor identify their hopes and expectations for the course. Together, they discuss these expectations and design the layout of the course in terms of learning activities, deliverables, and evaluation. A typical competency has 3-6 students and one instructor. The instructor and the students will meet 2-3 hours per week for 8 weeks in "Learning Conversations" (LC). The intent of a learning conversation is to be a place where students and instructors can make conceptual sense of the learning. This is done in a flipped-classroom type of method where students do initial learning on their own between LCs and then use the time together in LCs to ask questions and discuss the relevance of the learning. The three required learning types in any competency are conceptual, process, and metacognitive.

Conceptual learning is focused on connecting all learning to the fundamental principles of engineering. For example, if students were taking a competency in heat transfer, they would learn the concepts of conduction, convection, and radiation. Then they would connect these concepts to broader engineering fundamentals such as the law of conservation of energy and the 2nd law of thermodynamics. Learning activities in conceptual learning include reading, watching on-line videos, working problem sets, creating concept maps, and group discussion.

In process learning, students connect their conceptual learning to engineering practice. They do this by completing a Deep Learning Activity (DLA). Whenever possible, the DLA is work needed to support the student design project such as design, testing, or modeling. For example, in the learning of heat transfer, it is not unusual for IRE project teams to be designing heat exchangers for their clients. The act of completing that design would be a DLA for a heat transfer competency. If a heat exchanger design was not required to support a student project, students might design and conduct an experiment verifying heat transfer using physical equipment and instrumentation for their heat transfer competency DLA. As the domain of learning spreads across all of engineering, similar type process learning opportunities are found in abundance. During learning conversations, instructors help students make connections between their conceptual learning and their DLA, as well as provide technical assistance to students throughout their DLA.

Metacognitive learning happens through students planning their learning, organizing and reorganizing their factual and conceptual knowledge, reflection, evaluation of their learning, and using the reflections and evaluation to dictate future learning. Each student keeps a learning journal for every competency where they record this planning and organization and write the reflections and judgments. At the end of each block, students write a metacognitive memo analyzing their learning throughout the four competencies and making future learning goals.

4 Graduate and Employer Survey

In an effort to capture the essence of Iron Range Engineering graduates as compared to their peers from traditional engineering learning environments, employers and graduates were asked to rate each group using a 7-point scale: 1-far below expectations, 2-moderately below, 3-slightly below, 4-met expectations, 5-slightly above, 6-moderately above, and 7-far above. A score of 4 - met expectations was explained to be at the level that they believe a new engineer should enter their company to be effective in their work setting.

4.1 Method

There are 75 graduates of the Iron Range Engineering program. All 75 were emailed a request to complete the survey and pass it to their supervisor. 30 graduates took the survey (40% completion) and 18 supervisors took the survey (24% completion).

The questions related to:

- Communicating effectively
- Acting professionally responsible (prompt, responsive, represent company well)
- Ability to design systems, components, or processes to meet needs with constraints
- Engaging in entrepreneurial thinking
- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
- Ability to solve engineering problems
- Ability to function well on teams
- Displaying a recognition of the need for and ability to engage as an efficient learner
- Ability to lead and manage people
- Ability to lead and manage projects

Respondents were asked to first rate all new engineers in the company who were non-PBL graduates against this scale and then to rate PBL graduates against the scale. Following is a sample question:

"Rate other new engineers (you have supervised [for employer survey], your peers [for PBL graduate survey]): Are professionally responsible (prompt, responsive, represent company well)."

4.2 Results

Table 1 displays the results from the supervisor survey and Table 2 the results from the graduate survey. Figures 3 and 4 represent the same data in graphical form. On the graphs, categories have been arranged from left to right with categories on the left having the greatest deltas between PBL score and non-PBL score.

Table 1: Supervisor survey results (n=18)

	Average Score (from 7-point Likert Scale)		
	Non-PBL Graduate	PBL Graduate	Delta: PBL - Non-PBL
Communicate Effectively	4.4	4.9	0.6
Professionally Responsible	4.6	5.2	0.6
Design Systems	4.8	5.0	0.2
Entrepreneurial Thinking	4.1	4.6	0.5
Modern Tools Use	4.6	4.6	0.0
Solve Engineering Problems	4.4	4.8	0.4
Perform on Teams	4.3	5.3	0.9
Efficient Learner	4.4	5.0	0.6
Lead and Manage People	4.2	4.4	0.3
Lead and Manage Projects	4.3	5.1	0.8

Table 2: PBL graduate survey results (n=30)

	Average Score (from 7-point Likert Scale)		
	Non-PBL Graduate	PBL Graduate	Delta: PBL - Non-PBL
Communicate Effectively	4.7	5.5	0.8
Professionally Responsible	3.8	5.6	1.8
Design Systems	4.2	5.1	0.9
Entrepreneurial Thinking	3.5	4.8	1.2
Modern Tools Use	4.0	4.8	0.7
Solve Engineering Problems	4.1	4.8	0.7
Perform on Teams	3.8	5.2	1.4
Efficient Learner	3.8	5.4	1.7
Lead and Manage People	3.4	5.1	1.7
Lead and Manage Projects	3.8	4.8	1.0

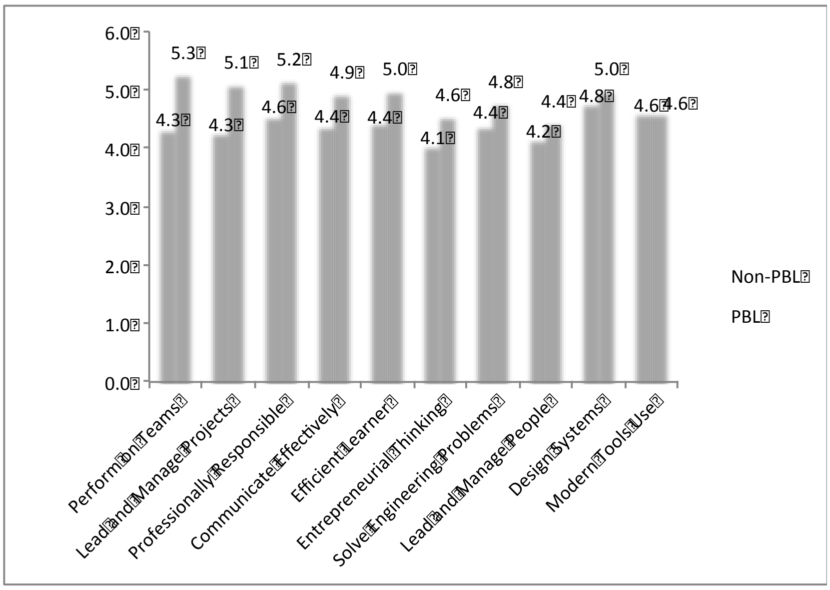

Figure 3: Supervisor scores of PBL vs. non-PBL graduate performance (n=18)

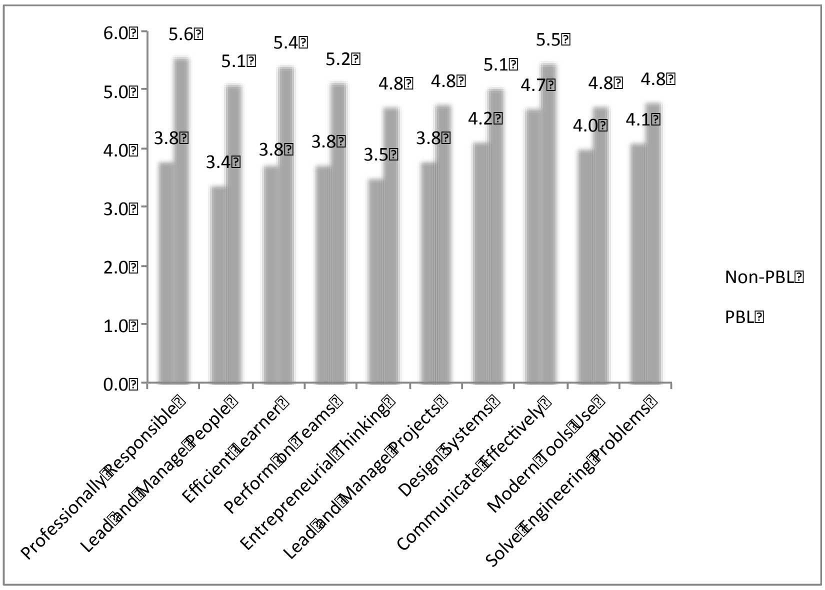

Figure 4: Graduate scores of PBL vs. non-PBL graduate performance (n=30)

The data was compiled; averages and standard deviations were calculated. A two-tail t-test was conducted comparing PBL vs. non-PBL means for both surveys. The only statistically significant difference between means occurred in the Efficient Learner category on the graduate survey ($t=2.154$, $p<0.05$).

Further results can be seen through the following trends and perceptions:

- On all 10 of the graduate survey questions and in 9 out of the 10 employer survey questions, the mean score for the PBL graduates was higher than the non-PBL graduates. The one category where this was not true was "use of modern tools" on the employer survey. In this category, the PBL and non-PBL graduates scored the same.
- The employers scored all graduates, PBL and non-PBL above 4 (met expectations) in all categories. Whereas the graduates rated themselves above 4 in all categories, but their non-PBL peers below 4 in 5 out of the 10 categories.
- Employers found the greatest difference between PBL and non-PBL graduates in "performing on teams," "lead and manage projects," and "being professionally responsible." Whereas, the PBL graduates found the greatest difference between themselves and the non-PBL graduates in "being professionally responsible", "leading and managing people", and "being efficient learners."
- Employers rated the PBL graduates highest in "performing on teams," "being professionally responsible," and "leading and managing projects." Whereas, the PBL graduates rated themselves highest in "being professionally responsible," "communicating effectively," and "being efficient learners."
- Employers rated the non-PBL graduates highest in "designing systems," "modern tools use," and "being professionally responsible." Whereas, PBL graduates rated their peers highest in "communicating effectively," "designing systems," and "solving engineering problems."
- Employers found the least difference between PBL and non-PBL graduates in "leading and managing people," "designing systems," and "modern tools use." Whereas, the PBL graduates found the least difference between themselves and the non-PBL graduates in "communicating effectively," "modern tools use," and "solving engineering problems."
- Employers rated the PBL graduates lowest in "modern tools use", "leading and managing people," and "entrepreneurial thinking." Whereas, the PBL graduates rated themselves lowest in "leading and managing projects," "modern tools use," and "entrepreneurial thinking."
- Employers rated the non-PBL graduates lowest in "leading and managing people", "leading and managing projects," and "entrepreneurial thinking." Similarly, PBL graduates rated their peers lowest in "leading and managing people," "leading and managing projects," and "entrepreneurial thinking."

4.3 Discussion

The mean-to-mean comparison resulted in only one statistically significant result. That PBL graduates found themselves to be more efficient learners than their non-PBL counterparts. There were 10 survey questions and 2 surveys for a total of 20 possible comparisons. While the other 19 comparisons did not result in statistically significant differences, there are several trends and perceptions worth noting. The trend that 19 out of the 20 questions had PBL graduates rated higher than their non-PBL peers and that all 20 questions rated the PBL graduates above 4-met expectations answers the questions "are the PBL graduates satisfied with their engineering preparation?" and "are employers satisfied with the engineering preparation of the PBL graduates?" Further evidence that the answer to these questions is yes, comes from additional comments made by the respondents:

> "I would say on average the students from IRE we have hired have been more mature and have further progressed along the development curve to be effective in real world industry." *Employer*
>
> "By a wide margin, I prefer working with the Iron Range graduates because they are so professional." *Employer*
>
> "I think that among my peers I am definitely advantaged in my interpersonal skills and people management. I also think that my ability to juggle tasks or multitask is also superior." *Graduate*

“I have found the feedback loop lacking with many of my peers. They seem to find it acceptable to not communicate the results or outcomes of work or projects. Often if feedback is desired it must be requested using specific details to get the full picture.” *Graduate*

The least positive comment made by an employer was:

“I think it's fair to say that IRE graduates come to us with better training in the soft skills (inter-personal), but slightly less thorough training in the hard skills (practice-specific engineering skills). They are excellent overall engineers, but they require a bit more help on the technical side at first. That said, they are quick and eager learners, and I think they understand where their weaknesses are.” Employer

The least positive comment made by a graduate was:

“At times, I believe there are areas that I am less proficient at in technical knowledge due to the time spent in other areas such as professionalism. However, I have been told how much more valuable I am than the other engineer who has 10-15 years experience, but is not allowed on certain client properties due to his negative unprofessional attitude. He has an obvious advantage from job specific experience, but I still find that he comes to me for help with technical questions such as statics problems or converting from degree, minute, second to decimal form.” *Graduate*

The results of perceived highest and lowest performance indicate the trends that leading and managing people and projects, being professionally responsible, being efficient learners, and performing well on teams are all areas where the PBL graduates excel. Areas where the PBL graduates are more evenly perceived with their peers are use of modern tools, entrepreneurial thinking, and designing systems.

Of further note, is the magnitude of differences perceived by the graduates as compared to the supervisors. Graduates showed greater amplitudes when comparing their performance to that of their peers. They also showed greater levels of dissatisfaction with their peers than was noted by the employers.

5 Conclusion

The new PBL curriculum adapted from the Aalborg PBL model has been continually developing over the past 6 years. The history, development trajectory, continuous improvement model, and curricular model have been described. A quantitative satisfaction survey has been deployed and analysed. Results have been communicated. The conclusions from this survey are that the graduates and their employers are satisfied with the engineering preparation of the PBL model. The impact of these conclusions will be that the developers of the program will use the information gained in their continuous improvement model. The root causes of both the areas of strength and areas of needed improvement will be identified. In practice, curricular aspects will be maintained in the case of strengths and improved where needed. For example, the use of modern tools has been highlighted as an area of potential needed growth. The next evolution of the curriculum will include special attention to new activities for students to acquire modern tool use. Future works will include a qualitative approach whereby graduates and their employers will be interviewed.

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Learning Pathway "Problem Solving and Design" at the Faculty of Engineering Science of the KU Leuven

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Abstract

The Faculty of Engineering Science of the KU Leuven has more than 10 years of experience in preparing their students for professional practice through a learning pathway called "Problem Solving and Design". This pathway consists of four courses, spread over the three years of the Bachelor program, in which students collaborate in small project teams on real-life engineering problems.

Recent insights in the learning pathway have led to defining three Design Pyramids. The central Pyramid shows the different steps of the design process: information gathering, problem definition, generation of ideas, modelling, schematically representing diagrams, calculating and experimenting, evaluation and decision making, and practical realization. This large pyramid rests on two smaller pyramids, which are indispensable in the whole of problem solving and design. The left one is about communication and cooperation in a team, the right one is about planning and project management. The paper elaborates on these Design Pyramids, and reports on (1) the student as an active learner while engaged in the real-life engineering project work; (2) the learning outcomes of the pathway and the competences preparing students for professional practice together with the quality assurance of the learning pathway; (3) the progress in the learning pathway, showing how the different modules in the three years of Bachelor build up, how they fit in our curriculum design, and how students are learning different competences all along the path and (4) the evaluation methods used, grading criteria and feedback sheets.

Keywords: engineering education; problem solving and design; transversal competences.

1 Introduction

For engineering curricula, design and application play an important role in addition to the development of theories. At the faculty of Engineering Science, the learning pathway "Problem Solving and Design" (PS&D) has been implemented to develop design competences. After ten years of experience, the Faculty noticed a clear need of students to be guided more intensively in getting insight in the process of designing. The main goal of this paper is to explain the construction of our design pyramids, being a visual summary of all design competences needed in the design process and conceived to be used in curriculum development and student guidance.

2 High-level overview of the learning pathway PS&D

Problem solving abilities and design capabilities are at the heart of our engineering education. To solve real-life engineering problems students must learn to apply the knowledge and understanding they have acquired in courses on science, mathematics, engineering fundamentals, and their branch of engineering. They need to develop an out of the box thinking concept to acquire a multidisciplinary attitude. For this purpose, the Faculty of Engineering Science of the KU Leuven established a specific learning pathway with the name "Problem Solving and Design" (Heylen *et al*, 2004; Heylen & Vander Sloten, 2007). This learning pathway consists of

- PS&D1: semester 1 of the Bachelor (year 1), 4 ECTS (European Credit System Transfer)
- PS&D2: semester 2 of the Bachelor (year 1), 3 ECTS
- PS&D3: semester 3 of the Bachelor (year 2), 4 ECTS
- PS&D5-6: semesters 5 and 6 of the Bachelor (year 3), 9 ECTS.

A follow up course is organized in most of our master programs. The learning pathway is also an important preparation for the Master Thesis. We have chosen not to include the Master Thesis in the learning pathway PS&D as the Master Thesis has numerous other learning outcomes.

Some key characteristics of the learning pathway include:

- Students working with open, real-life engineering problems (in some projects companies are involved)
- Students working in teams of up to 8 persons
- The teaching and learning method is project-based
- The problems always require integration of knowledge from several disciplines acquired in different courses
- The design of a solution and the practical implementation play an important role.
- Strong emphasis is placed on transferable and transversal skills such as written and oral communication, working in groups, leadership, project management, responsibility and norms of engineering practice, taking of initiative and entrepreneurship.

3 The design pyramids

The learning pathway PS&D has been designed by the Faculty of Engineering Science of KU Leuven, and is built in function of the design pyramids shown in figure 1. Designing has been defined as follows:

> *Designing is a structured process in which, after analysis of a technical and/or socio-economic problem, knowledge and science is applied and/or developed in order to create new or improved products, processes or systems. Several variants need to be lined up, evaluated, validated and optimized to achieve a usable end result with clear added value that meets several clearly defined constraints or boundary conditions.*

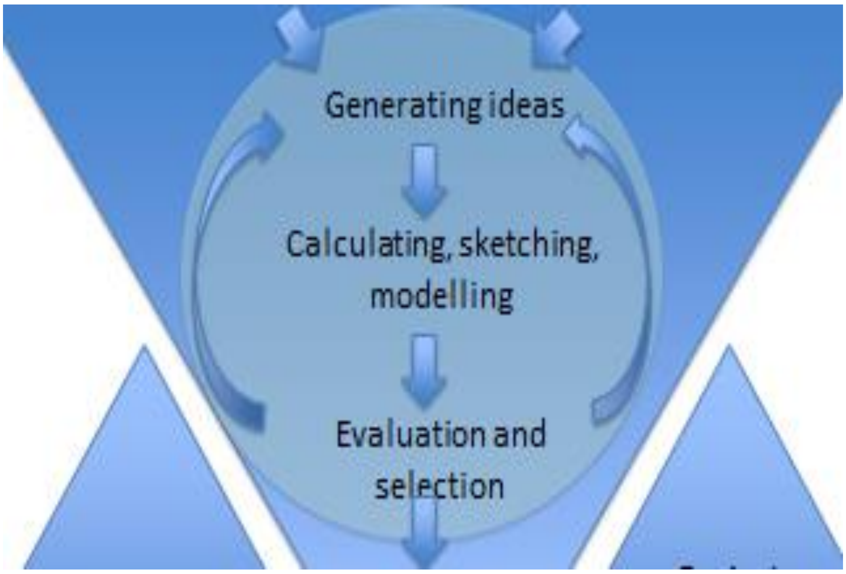

Figure 1: Design Pyramids

Our design pyramids, based on Davis *et al*. (1996), have operationalized this concept, showing the different steps of the design process that are involved. These are described in more detail below.

At the top left of the pyramid we have Information gathering. This includes identifying, locating and obtaining the required data, learning to use the university library, conducting searches of literature, use data bases and other sources of information. It also includes an appreciation of the different sources of data and a critical evaluation of the information found.

At the top right of the pyramid we find Problem Definition. This includes the identification of the problem, detection of the technical and non-technical requirements, and as such clarifying the specification. Students must also take into account societal, health and safety, and environmental constraints. In some cases also commercial constraints are taken into consideration.

In the middle of the main pyramid lies the heart of the designing process which is iterative and may comprise many cycles! It generally consists of:

- Generating ideas. Students are taught the techniques of brain storming, and are encouraged to hold such sessions, using a board to gather and consolidate their ideas. They are encouraged to be creative, to bring together different ideas to generate new concepts, and to develop new and original ideas and methods. They always need to integrate knowledge from different branches, taught to them in different courses, and to combine theory and practice.
- Calculating, schematically representing diagrams, modelling, experimenting. Students are taught to make sketches, and to model according to rigorous techniques, using state-of-the-art modelling tools. Students have to select and apply relevant analytic and modelling methods, including mathematical analysis and computational modelling. They learn how to conceptualize engineering models, systems and processes. Students have to design and set up practical experiments and collect the appropriate data from these experiments. Workshop and laboratory skills must be applied. Computer simulations can be used where experiments are not feasible.
- Evaluation and decision. Of crucial importance is the critical evaluation of results. The recorded experimental data must be interpreted. The designs must be assessed. Students learn to evaluate their choices and are asked to describe their arguments pro and contra. They have to critically compare different options and solutions. They learn to draw the necessary conclusions, which might lead to redefining the problem and/or the need to generate new ideas. Most often a new iteration of the design process needs to be executed.
- Construction/Realization. In the learning path, there is also room for the development, implementation and realization of the designs made. Often students will build a prototype. They will need to select appropriate equipment, materials and tools, they will need to consult technical literature, codes of practice and safety regulations. It will be important to understand applicable techniques and methods, and their limitations. Students might need to investigate the application of new and emerging technologies. Also here workshop and laboratory skills will need to be applied.

The large design pyramid rests on two smaller pyramids, which are indispensable in the whole of problem solving and design. The left one is about communication and closely cooperating in a group. Students are actively coached in this process. They learn to hold formal meetings, using an agenda and writing minutes. They alternate in taking the lead in such meetings. They learn to function effectively as an individual and as a member of a team. Peer evaluation is used to give feedback to the students about their functioning. In PS&D3 some groups are composed of different disciplines and levels, where our students and students from the faculty of industrial engineering work together on a project.

For all projects written reports need to be written, often an oral presentation is also required. For PS&D3, a demonstration day is organized for the public at large, and students need to orally report on their project. In some master projects, multicultural/international groups are formed, giving the students the opportunity to work in an international context. Attention is paid to the critical attitude of the students: do they see the limitations of their design, and can they give the necessary arguments for the choices they made during the whole process.

For the aspects of technical reporting, the Faculty established a specific learning path. A website about technical reporting across the engineering curriculum (https://eng.kuleuven.be/english/education/reporting/) offers advice and good practices, grading criteria and feedback sheets, both for written as for oral communications. These are used in the PS&D learning path, but also in other courses of the engineering program, and for the master thesis.

The right pyramid upon which the main design pyramid is resting, concerns project management. From the first PS&D, emphasis is put on planning. The projects always span a large time frame, from several months to a whole semester, to a whole year. Furthermore, as the work is done in teams, planning should be done both in time and in human resources. Financial resources are part of PS&D2: students get a budget for the realization of their prototype. Also risk management is taken into account. Next to project planning and management, students are asked to demonstrate awareness of health and safety issues. Sometimes economic and legal issues should also be taken into consideration.

4 Learning outcomes and quality assurance of the PS&D learning pathway

For each module of the PS&D learning pathway learning outcomes have been described. The formulation of these learning outcomes are based on the elaboration of the module on (1) the design pyramid with its different steps of the design process and on (2) the different competence areas of the ACQA (Academic Competences and Quality Assurance) framework (Meijers et al, 2005). At the Faculty of Engineering Science, the ACQA framework is used to describe all curricula (Londers et al., 2011). Further on, learning outcomes of all modules within the learning pathway have been aligned.

By defining in detail all individual modules of the PS&D pathway, disturbing overlap can be avoided. As the learning outcomes of the modules are based both on the design pyramid and the ACQA framework, learning outcomes have been formulated using standardized vocabulary, recognizable for all stakeholders.

5 Progress in the PS&D learning pathway

In each PS&D course, the students carry out an entire design project, passing through all stages described in the pyramids. All assignments are designed by the staff, taking into account all stages defined in the design pyramids. In a first project (PS&D 1) each team of students executes a design assignment, which is embedded in a real context. In 2013-2014 this was for example, constructing a moving vehicle (without using a motor) with some prescribed properties and criteria that must be met by the vehicle. This design builds only on basic knowledge in mathematics and science from secondary education, and as a result a prototype is expected made from simple construction materials (paper, wood, Lego, K'NEX building elements, etc.), that needs to "prove" its functionality in a contest between the teams.

The follow-up projects in PS&D 2, PS&D 3 and PS&D 5/6 are becoming more complex, i.e. less defined and structured. More scientific and technical knowledge needs to be employed and combined. Furthermore, students need to gather new needed knowledge and they will learn new techniques or skills when necessary. At the same time, more and more independence from the student teams is expected in planning and execution of the project.

The PS&D projects evolve on the one side in increasing complexity and on the other side in decreasing control. By executing these projects, students will deepen and widen their expertise in designing. This gain in the learning process can be depicted as a spiral (Figure 2, www.skoolbo.com/img/about/sprial.png), where complex ideas (in this case 'design') in their entirety are offered to students. In the beginning on an easy level and thereafter ever on a higher level (Harden & Stamper, 1999).

Figure 2:
Spiral learning pathway

When we look at different characteristics of our PS&D projects, we can describe the progress in the PS&D learning pathway (for the three first courses) as follows.

- Authenticity

- PS&D1 and 2: Fictitious problem, framed in real context; Identical assignment for each team.
- PS&D3:
  - Assignment is based on real situation and/or links up with existing research
  - Assignments are supplied by the different disciplines
  - Same assignment for 2 to 4 teams.

- Structure
  - PS&D1
    - Problem definition and specifications given in text format
    - Partial assignments are given
    - Experiments and measurements that need to be performed are given.
  - PS&D2
    - Problem definition and specifications given largely in text format
    - Partial assignments given to some extent
    - Experiments and measurements that need to be performed are given to some extent
    - Execution of experiments and measurements are done autonomously.
  - PS&D3
    - Objective is given, specification only partially given, it needs to be refined by the students
    - Guidance on partial assignments.
- Course integration
  - PS&D1: For knowledge comes from secondary education.
  - PS&D2: For knowledge from first semester: basic knowledge of mechanics and electronics.
  - PS&D3: Integration of knowledge acquired in different courses; guided acquisition of new discipline-expertise.
- Tools and methodology
  - PS&D1: Material is offered; step by step guidance in the design process with clearly articulated partial assignments.
  - PS&D2: Technology is offered through (self-) instruction and partial assignments.
  - PS&D3: Custom guidance for use and choice of technologies and methodologies.
- Requirements for finished products
  - PS&D1: Prototype made of easily available construction material.
  - PS&D2: Prototype, some components are made available.
  - PS&D3: Functioning prototype (some parts are available) or model.
- Guidance
  - PS&D1 and 2: Teams work independently – guidance continuously available during sessions.
  - PS&D3: Teams work independently – guidance part time available during sessions.
- Project management
  - PS&D1: Per session is recorded what the group will do.
  - PS&D2: Students are partially responsible for planning and timing.
  - PS&D3: Deadlines are known, students are fully responsible for planning.

6 Evaluation methods used

The evaluation of the PS&D courses is based on several pillars. For reporting (both written and oral reporting), the Faculty of Engineering Science has developed extensive grading criteria and feedback sheets (Versteele *et al*., 2012; 2013). For other aspects, the tutors grade the groups, and peer assessment is employed in addition (Heylen *et al*., 2006). For projects more advanced in the learning pathway also external graders are asked. The current situation for the first three courses is as follows:

- PS&D1: peer assessment, combined with grading by tutors who guided the team;
- PS&D2: peer assessment and presentation to tutors and a semi-external jury, composed of tutors of other teams;

- PS&D3: peer assessment, presentation and demonstration for a wider public during the demonstration day, assessment of final reports.

We are currently working on an assessment grid based on ICE (Ideas Connections and Extensions) rubrics (Young & Wilson, 2000; Platanitis & Pop-Iliev, 2010), where each element from the pyramid and the corresponding competences students should acquire, get a place. We are convinced that feedback to students is of paramount importance. Ideally, students become conscious of their evolution and the competences they are acquiring (or are still lacking!). A tool that maps these competences visually over the years is being considered.

7 Conclusion

In this paper we presented our Design Pyramids, which are at the centre of our learning pathway on problem solving and design, a crucial learning pathway in our engineering education. The definition of designing, combined with the clear pyramids give a sharp framework through which our students acquire insight in the process of designing. We use these pyramids in each course of the pathway, to explain the students how their tasks and partial assignments fit in the design process. In this way students understand better which partial assignments focusses on which part of the pyramids.

The pyramids offer a framework that will allow us in the future to give better, more concrete and targeted feedback to students about specific elements in the design process. Ideally, students become conscious of their evolution and the competences they are acquiring.

Future work therefore consists of making the feedback more concrete, and showing the progress students make in the different parts of the design process through the different stages of the learning pathway. Ideally this feedback is visual, and based on a portfolio that grows with the progress of each student.

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Activity Led Learning Environments in Undergraduate and Apprenticeship Programmes

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Abstract

Transversal Competences are considered to be key developmental goals in higher education in preparing students for employment. This paper proposes that the faculty of judgement is the principal common cognitive component in transversal competences and that Activity Led Learning (ALL) can be used in both undergraduate programmes and the specific work related learning environment of apprenticeships to develop judgement capacity. The programme of research studied two categories of learners, one was a 3rd year students on the BEng Aerospace Engineering programme at Coventry University UK and the other group, were BTEC level 3 apprentices employed by an engineering company in the north-east of England. Employing a phenomenological methodology, the activities, meetings and dialogues of both groups of learners were observed, recorded and analysed together with copies of their meeting records and logbooks. Analysis of the records indicate that the application and exercise of transversal skills is a significant feature of the learning experience in which learners exercise complex heuristic and rational judgements.

Keywords: engineering projects; activity led learning; judgement; transversal competencies

1 Introduction

The two case studies referred to within this paper were selected as representative of a programme of wider research at Coventry University into Activity Led Learning and whether the ALL environment can enable the development of professional judgement capacity in undergraduate and apprentice learners. Defining professional judgement and judgement capacity is quite difficult. Professional judgement is often thought to be quite rational and meticulous though there is a considerable body of evidence to the contrary and the domain specific knowledge of new profession entrants is similar too long standing experts (Eraut 1994: 155,129). Expert professional performance may however be characterised in the way that professionals rapidly define and resolve problem spaces viz. in the way they have developed the capacity to exercise judgements. This paper aims to show that in ALL environments, learners exercise and develop skills in making professional judgements that are distinctive features of transversal competences.

1.1 Transversal Competence and Judgement Capacity

The importance of transversal competencies and judgement capacity in learning and professional practice has been considered by a number of researchers. Down et al (1999) argue that the development of skills attributes in higher education and the development of key competencies in vocational training are similar concepts that both require the ability to make sound judgements. Trevelyan (2010) posits that the social interactions between engineers in the workplace and those of learners in cooperative learning environments are very similar. Practice is dependent upon the distribution of expertise that is difficult to transfer and often has little common understanding. He further questions whether current PBL models are sufficient when he claimed that they do not explain the phenomenon of error detection or the considerable time and effort exerted in informal communication. A study by Down (2000) on how effectively key competencies were integrated into training revealed some degree of confusion about the identification of key competences. These studies illustrated the difficulty in interpreting and transferring higher level statements and criteria for skills development and this paper proposes that these skills should be viewed at the level of human cognition known as judgement. Further to this point, Cowan (2010) discusses the central role of judgement capacity in lifelong and personal development and self and peer assessment and that such judgements should be based on fact rather than values or systems of belief. In contrast to the widely held view that engineering is technical work, problem solving and design carried out in isolation, Trevelyan (2010) described engineering practice as a predominantly social activity between engineers necessary to delivering predictable outcomes from unpredictable from human interactions. Hager (1999) considered making better judgements to be an ideal objective of learning in the workplace and that improvement could be expressed as the capacity to make appropriate judgements.

1.2 Activity led Learning

Activity Led Learning (ALL) is defined as "a self-directed process in which the individual learner, or team of learners, seek and apply relevant knowledge, skilful practices, understanding and resources (personal and physical) relevant to the activity [being undertaken]" Current ALL practice at Coventry University is based on work by Wilson-Medhurst et al (2008:2) and earlier work on problem based learning PBL by Savin-Baden(2000) who states that PBL was developed at McMaster University and cites Barrows & Tamblyn's (1980) claim that learning through the examination and solving of problems is more effective than memorising knowledge for developing a usable body of knowledge. The central premise of ALL is that the learning experience is based on a problem based activity with the learners at the centre of a community of inquiry. The problem and activity are placed before knowledge and the learner is placed in a challenging learning environment to make connections between what they experience through action and knowledge. ALL is thought to provide learning environments in which judgements can be exercised to develop the capacity to make professional judgements.

1.3 Key Competences

There have been numerous initiatives to define key competences or construct frameworks of essential transversal competences. The following two cases are provided to illustrate the outputs typical of such initiatives. They may be strategic statements that reflect broader national objectives such as the recommendations made by the European Parliament on key competences for lifelong learning on 18 December 2006. The framework listed below, proposed a definition for eight key competences and the associated essential knowledge, skills and attitudes. (EU Parliament & EU Council 2006)

1. Communication in the mother tongue,
2. Communication in foreign languages,
3. Mathematical competence and basic competences in science and technology.
4. Digital competence
5. Learning to learn
6. Social and civic competences.
7. Sense of initiative and entrepreneurship
8. Cultural awareness and expression,

More specifically, Serrano et al (2011) proposed a list of attributes of transversal competences expressed at a behavioural level having the following common fundamental characteristics.

1. They must integrate knowledge, skills or abilities and attitudes or values.
2. They entail an interrelation of capacities and are manifested at the level of behaviour.
3. They possess a practical dimension, regarding execution.
4. They are developed in a specific context, normally complex and changing.
5. They are global in nature, in order to respond to problematic situations.

There is no inherent way of knowing from these frameworks to what extent the competences should be exercised or how they can be combined. This implies self direction and would appear to support the position that judgement is a core definitive function in their execution rather than adherence to a set of rules. This presents some difficulty in any attempt to define any kind of skill within frameworks that are criterion based. On the other hand, transversal skills in professional practice require the individual to be able to exercise judgements in particular contexts some of which are difficult to measure and apply criteria. Often, judgement has to be exercised in uncertainty and in the absence of some types of knowledge and professional judgement can be erroneous. This is in contrast with the general public view of scientific reliability in professional judgement (Eraut 1994:155). Eraut (1994:124) also held the view that attempts to develop frameworks of professional competences had all failed and referred to Merleau-Ponty's claim that perception and understanding is about acquiring flexible styles of behaviour rather than rules (Merleau-Ponty 1945). Professional competence may be more readily defined by considering transversal skills at the level of judgement and expert judgement capacity as opposed to trying to capture then in higher level statements. For example we can examine an instance encompassing the five aforementioned attributes posited by Serrano et al (2011). The following extract of learners employing transversal competences in an uncertain technical domain is taken from a larger study on developing judgement capacity through Activity Led Learning.

1.3.1 Apprentices' Background

One team of engineering apprentices were working on very earliest stages of their project plan, producing a Gantt chart, risk matrix, risk register, ball park costing and basic technical detail. In effect they were defining the initial problem space of the project. Their main activity involved discussion of various priorities, necessary conditions and desirable attributes and researching potential options with an i-phone and mobile internet connection. In the interaction, each apprentice brings different views of technical knowledge, skill sets and values to the problem space and these activities could be considered implicitly to integrate knowledge, skills or abilities and attitudes or values. At the level of judgement, what can be discerned of skill becomes much more detailed. From the apprentices' accumulated experience of machining practice they have some information and analogies from which to judge the absence of necessary information and make judgements about the composition of the problem space. This includes judgments of discrimination, relevance, appropriateness and value and hypotheticality. Time estimates were optimistic and heuristically based upon their experience of machining and how much effort they think is involved. They have no specific data to make rational judgements of inference and the only information that the immediate future will present is related to the kinds of material they might use. Despite having little concrete information they arrived at an unqualified but not unreasonable idea of the effort, time and potential obstacles to their project. Their initial estimate for costs was £21K. The judgements they exercised are almost entirely heuristic at this stage but their justifications viz. judgements of hypotheticality, factuality, counterfactuality are debated quite forcefully. Their risk register was detailed with ten operational threats to the project, also indicating they have made numerous judgements of hypotheticality, factuality and counterfactuality including judgements of relevance, inference, and appropriateness. (Igarashi et al 2014)

2 Methodology

The research question asks 'What is the learners' experience of making judgements in the ALL environment and what does that tell us about the construction of ALL to promote the development of capacity for professional judgement?' When an individual exercises judgements they intend a state of affairs about a particular proposition. Judgements are made in order to make sense of our thoughts whenever a situation is perceived or cogitated, and what we intend by our judgements is what we make of the world (Sokolowski 2000). We make judgements of discrimination i.e. identity, difference, similarity, membership; judgements of composition, division, inference, relevance, causality, analogy, appropriateness, value, hypotheticality, counterfactuality, practicality, factuality, reference, measurement, translation and instrumentality (Lipman 2003). Judgements, are resistant to measurement particularly in complex contexts, however all premeditated action must be preceded by one or more judgements. When we observe the actions of others we actually observe the 'residues' of their judgements. By recording those actions and analysing for them for meaning in context we are able to infer that judgements of a particular type were made. A phenomenological methodology and research method was adopted for this study in order to capture the phenomena of judgement and understand the learners' experiences of making judgements as they occurred (Gray 2009).

2.1 Method

The dialogues and actions of the learners were recorded as they engaged in ALL in order to acquire an audit trail from which their judgements can be inferred. Manually recorded observation and interviews learner and learner's logbooks were the research tools used for data capture. Observation permits the learner's interactions with their environment and other participants to be captured as they occur. Interviews and log books enable the learners to record their actions and decisions and particularly those that are most salient so that the problem space can be inferred as the learner intends it. These records of learners' actions and dialogues are then examined in the context in which they occurred to infer the type of judgements that were exercised. The following extract from a learner logbook Fig 1. illustrates the extraction method.

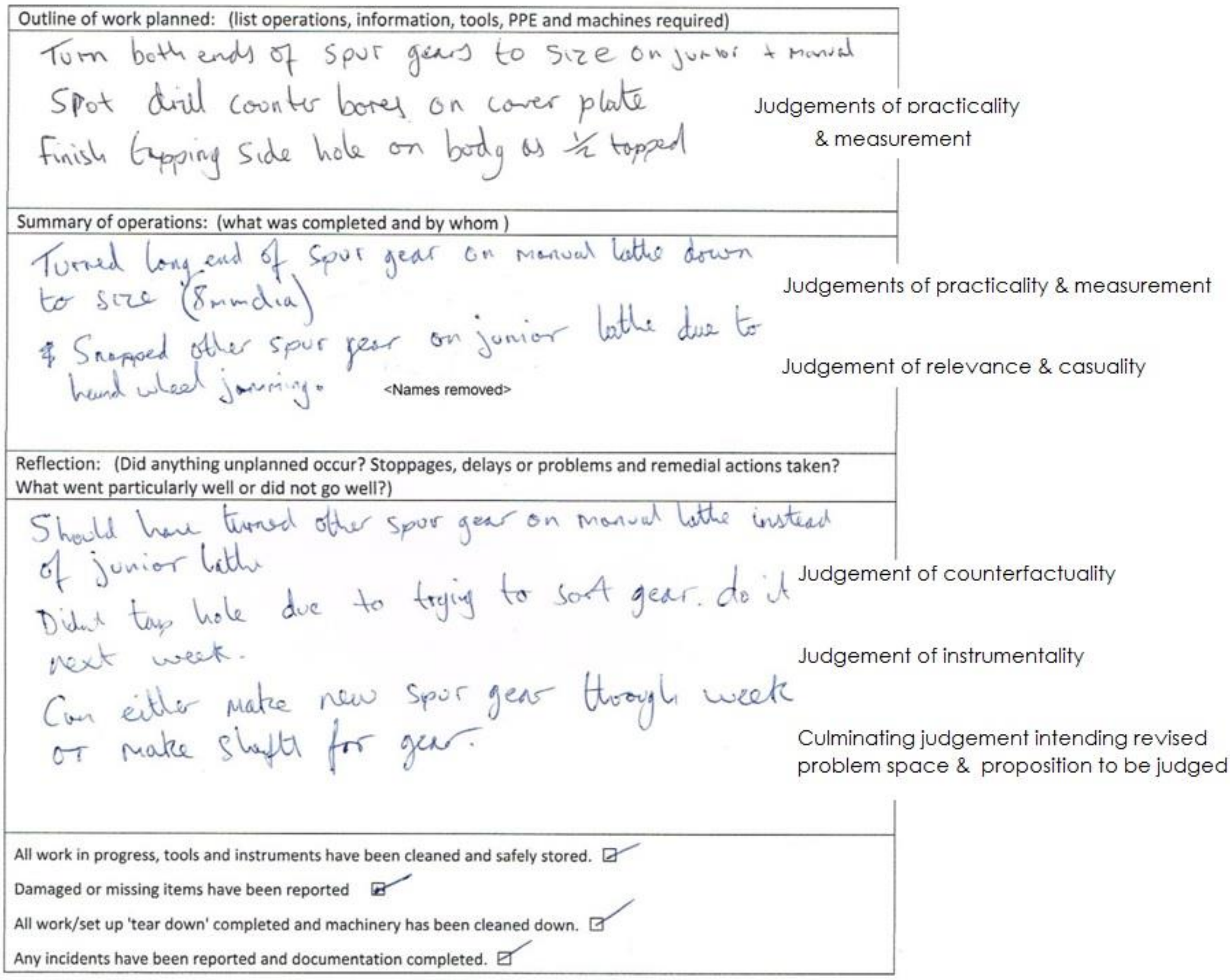

Figure 1: Apprentice learner logbook and inference of judgement.

It is not possible to know all the judgements that were made since not all judgements determine in an observable outcome. By using phenomenological methods the assumptions that normally attend the observations of others are suspended in order that the experience of making judgements can be understood purely from the perspective of the research subject (Lester 1999).

3 Research Study

3.1 Student Project Outline

3.1.1 Apprentices' Background

The apprentices in this study were employed at a precision engineering company that produces high integrity valves for the oil and gas industries. They have a four year apprenticeship consisting of a BTEC level 3 qualification and a National Vocational Qualification (NVQ) with specific machining competence pathways. In addition these apprentices also participate in an extension development programme the purpose of which is to determine if any of them have the potential to develop as production engineers. For this purpose the extension programme is specifically designed to stretch the learners so that they have to exercise judgements in a professional context and understand if any of them show the potential for further development. This study is taken from research into that programme of work.

3.1.2 Apprentices' Project

12 apprentices took part in the study and were observed during working hours in tutorial sessions specifically allocated for the purposes of this project. The cohort was divided into 4 teams who are tasked to work as consultant engineers and their task was to conceive, cost, design and make a CNC machine work-holding system for a component that was known to be difficult to restrain and machine. The project was of 33 weeks duration and there was a minimum of 3.5 hours of dedicated tutorial time per week. The apprentices all had between 2 and 3 years of CNC machine operation experience and were supported with tutorial lectures on project management tools and methods, mathematics, mechanics and work-holding principles. Each team competed against the others and had to 'pay' penalties for over running planned deadlines and consultant fees for any additional assistance they required. They were assessed in three stages, firstly on their initial design concept, research, design proposal and costing. The second assessment was on specification compliance, project planning, location and clamping method and kinematic and mathematical analysis. Their final assessment was of the apprentices' logbook, state of completion of their solution and a presentation and defence of their total solution. The teams were only given very broad assessment and format objectives, for example to present their concept design as if they were presenting to a client or to present their project plans and costing as if to their own directors. As part of the learning and assessment they were required to research and make judgements as to what content and level of detail they considered to be appropriate for each presentation. Each team maintained a weekly logbook of their work detailing their decisions, actions and reflective judgements. The apprentices were required to machine and build their design solution.

3.1.3 Undergraduate Aerospace Students' Project

The focus of the aerospace project was the design of a nose wheel and landing gear for a light aircraft. There were 36 students divided into teams of 6. The students were in the 3rd year of their undergraduate studies and had experience of team engineering project work from previous years. The teams were not explicitly required to compete with each other but worked independently of other teams. The project was 27 weeks in duration, some tutorial support was given each week but the majority of the project work was done in the students' own time. The weekly tutorials covered guidance on project planning and documentation methods and in addition quite specific guidance and assessment criteria were given to the teams on what they were expected to provide at each stage for assessment purposes. The specification for the design exercise was very comprehensive. The students were assessed in 2 stages, the interim phase was a presentation of trade-off studies, design analysis calculations and overall design description and the final assessment was a presentation and report of their design. This was marked on research, design, design calculations, specification compliance, project planning and management, design justification. Client changes to the specification were introduced part way through the project as part of the overall challenge.

3.2 Observation and Recording

A total of 77 opportunistic observations were made of the apprentices, and 39 of aerospace undergraduate groups throughout the duration of their projects. The actions, decisions and dialogues of the learners were manually recorded as they occurred. The apprentices' logbook records were also used and comprised 112 individual entries. The analysis relies on interpreting the records according to the taxonomy of judgements proposed by Lipman (2003) and the systems thinking model proposed by Kahneman (2011) in which judgement may have either a heuristic or a rational component. Lipman's taxonomy provides a schema in which judgements may be categorised. The categories do not however provide a way to explain how some judgements are observed to be made quickly and without cognitive effort while in different contexts judgements in the same category are made after some cogitation and reasoning about the proposition being judged. Kahneman et al (1982) through exhaustive empirical trials concluded that in reasoning, humans tend to heuristic judgements that are fast and efficient in preference to rational judgements that are slow and require effort. Cognition tends to heuristic judgements where time is limited, information uncertain or if the problem is complex or demands cognitive exertion. Heuristic judgements are useful in reducing problems to simpler forms and are most effective where the individual has analogies from previous experience to draw upon. They are however driven by evolutionary cognitive biases that can result in serious errors in reasoning.

4 Results

4.1 Phenomenology of the Apprentice Group

4.1.1 The Effect of the Project Environment

The teams of apprentices were observed to work through the development of their design in broadly similar stages. Every team member had some experience of CNC machining and a general appreciation of work holding methods with vises and clamp sets but they have no experience of working in teams on an extended project of this complexity. With limited analogies of the nature of the problem, their initial problem space definition is heuristic, rapid and quite vague. No technical information was provided other than some tutorial work on project management tools, locating theory in jigs and fixtures and the mathematical modelling of cams and toggle clamps. The learners had to be able to transport this knowledge and apply it in the context of their particular design. All other knowledge required for their particular solution had to be discovered and judged relevant, appropriate and composite to the problem space and its solution.

4.1.2 The Effect of the Learners' Intentionality in Judgement

The problem space is not developed sequentially and logically but changes direction regularly with propositions and concepts being re-activated and re-judged. Disjunctures occur when conflicting information is discovered and judgements have to be made about the best way to proceed. Heuristic judgements feature at all stages, however the problem space gradually becomes more rational as it is advanced by their judgements. The project activity drives knowledge seeking but judgements are dominated by the teams' abilities to cope with each other's intentionality. The learners' activities and intentionality of the problem space depends heavily on sharing cognition and experience through discussion. Disagreements on judgements of appropriateness, relevance, practicality, hypotheticality and factuality are a frequent and necessary attribute of the discussion dynamic that compels re-judgement of propositions and further investigation. Some of the proposed solutions are intended by one team member who acts authoritatively and appears to arise in their experiences. When these propositions are unchallenged the heuristic judgement becomes sanctioned and there is little possibility of change. That individual may not necessarily be chosen to lead the team. Leadership in the teams was therefore both implicit and tacit rather than explicitly invested in any one person.

4.2 Phenomenology of the Undergraduate Aerospace Group

4.2.1 The Effect of the Project Environment on Judgement Capacity

The Aerospace students had prior experience of working as teams on various projects since their first year at university. The project assessment criteria determined to a large extent the scope and depth of the problem space removing the necessity to make heuristic judgements about it. In effect the initial problem space definition for these students was partly performed for them. This potentially reduces any opportunities to exercise an important part of expert judgement, namely, the initial autonomous perception of the problem and their intentionality of defining the problem space with any knowledge that may be relevant, appropriate and composite to the solution. The comprehensive design specification put the students in a position to move quickly on the actual trade studies and design of their solution. Tutorial time was limited and much of the work was done in the students' own time.

4.2.2 The effect of the Learners' Intentionality in Judgement

In marked contrast to the apprentices they established face to face meetings for the purpose of labour division, project management, control and progress evaluation only and technical work on the design was mostly carried out by the team members in isolation. Team members selected specific tasks in line with their own interests and capabilities, for example trade study research, calculating the maximum permissible nose wheel mass, braking requirements, the wheel retraction mechanism etc. Their planning appeared to be the result of rational judgements, however, the lack of discussion other than at pre-arranged meetings means they each had to place complete trust in other team members to finish their task. A decision to trust involves a complex heuristic judgement of intention attribution that is subject to the bias of representativeness. In consequence, the team meetings have to allocate increasingly more time to cope with poor engagement and input from a few team members in whom trust was misplaced. All of the teams observed experienced some difficulty exercising judgements to cope with lack of input from some team members.

4.2.3 The Effect of Reduced Collaboration on Judgement Capacity

Trevelyan (2009) notes that the distribution of expertise through communicative activity accounts for a significant proportion of the total activity in professional engineering practice. The view that engineering practice is predominantly technical in nature is also criticised by Trevelyan (2010:386,387) who maintains that engineering is largely dependent on transversal skills to transfer information about uncertain, unpredictable and difficult to understand practices. This study indicates that working in isolation does not appear to bestow any benefits in a situation where collaboration and communication help to drive counterfactual judgements of appropriateness, relevance, hypotheticality and practicality through informal dialogue. The following extract from the aerospace students' dialogue in the early stages of the project is illustrative.

> "I think we have all done research in the past week."
>
> "The power point is blurring the edges around what we actually need to do, I just want to get this trade study completed."
>
> "Do we need to do a project brief? We've done most of the project management."
>
> "The design will be more concise if we all do it together, rather than in pieces."
>
> "We don't need to design both drum and disc brake systems."
>
> "What about the envelope, do we have to assume water tightness?"
>
> "Which way does the wheel retract?"
>
> "Link up with A, she needs to be working on the wheel".

From this brief exchange the uncertainty of their current position can be inferred. Without a mutual understanding of their progress they have to propose a state of affairs and make heuristic judgements of factuality viz. whether the evidence they have is sufficient and having to proceed with the uncertainty. One of them expresses the view that working together would produce a better outcome. They have become aware of the piecemeal approach and made the hypothetical judgement that it is not an appropriate way to proceed because the outcome would be comprised of parts that are not coherently representative of the whole, thus expressing judgements of composition, division and relevance about the problem space. During the conceptual and design stages fewer iterations and re-activations of ideas were observed. Solitary work creates fewer disjunctures that stop the learner and compel them to re-examine their current understanding. Moreover, there is the potential for their final design solution to become a compromise of individual thinking rather than something that reflects the total capacity of a team.

5 Conclusions

5.1 Constructing the Environment for Judgement Capacity

In professional practice, engineers face new and unusual challenges and expert practice can be defined by the way judgements are exercised when knowledge of a problem is limited Eraut (1994:120,129). The study indicates the importance of exercising judgement in transversal and technical competences in engineering practice. Both teams relied heavily on communication and collaboration but exercised them in different ways. The apprentices used a more informal approach and communicated even on technical issues that had been allocated to team members. They had little explicit steer and were permitted to exercise judgements as they thought appropriate on both their project management, design and the way they presented it. The undergraduates were given explicit guidance on the content and detail required in their presentations but were able to exercise a range of judgements in technical development and in the transversal competences typical of project management. The undergraduate groups made the judgement to distribute expertise in a formalised way but relied upon each team member to work in isolation, meeting only to discuss progress and share expertise post ergo. From these two case studies it can be inferred that the way in which the project information is presented to the problem space has a direct impact upon the way learners exercise judgements in the initial stages of problem space definition. The study suggests that the ALL environment can be constructed to enable learners to exercise judgement capacity in technical and transversal competences. Particularly the project specification needs to be considered carefully to permit the learner to develop skills in problem space definition by exercising judgements in the initial critical stages of problem solving.

5.2 Judgement in Transversal Competences

The importance of discussion as a means to distribute cognitive load and knowledge can also be seen from this study. The actions typical of problem solving require the exertion of judgements of analogy and discrimination, composition, relevance and inference, appropriateness factuality and hypotheticality. These judgements are exercised across both the technical domain and the socio-technical domain of leadership, communication, collaboration, planning, intention attribution and managing uncertainty. When project teams engage in collaboration and dialogue they create a whole series of cognitive disjunctures that flow from one into the next, each one stopping the learner, compelling them to exercise judgements of counterfactuality and reconsider propositions and review their understanding. Where dialogue is absent there are few opportunities for these noumena. The results of the study suggest that Activity Led Learning can provide useful environments for the development of transversal competences through developing judgement capacity. It also suggests that where the development of judgements and transversal skills is a pedagogic objective then the ALL environment can provide opportunities to exercise complex judgement by constructing it in a particular way. Providing an environment in which all the initial information is given at once, the learner can intend a problem space, discover information and successively re-define the problem space by seeking new information and forming propositions. Maximises disjunctures fully exercises the learners' intentionality and judgement. ALL effectively enables the exercise of judgement capacity in programmes in ways that are broadly comparable to the need to exercise judgement in work based projects and those judgements are a necessary component in transversal competencies. Moreover learning environments in both undergraduate programmes and in work based learning programmes are conducive to the effective application of Activity Led Learning paradigms.

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100 fears of solitude: working on individual academic engineering projects remotely

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Abstract

The UK's Open University has been one of the leading open distance learning universities for over 40 years. It currently has around 200,000 students. Its engineering programme supports several higher education qualifications. Central to them is the BEng(Hons). This general engineering qualification is partially accredited for Chartered Engineer by several UK professional engineering institutions and fulfils an important role in the provision of engineering higher education in the UK. One of its final modules is The Engineering Project (T450) which has been taken by over 2000 students since its introduction in 2004. It is now in its last presentation with over 400 students registered. The project is intended to be open-ended, authentic and largely selected by the student. The module acts as the principal synoptic assessment for the BEng(Hons) where students are expected to bring together their learning from throughout their undergraduate studies. The project and assessment are based on the requirements in UK-SPEC, UK Standard of Professional Engineering Competences (Engineering Council, 2014) in particular an opportunity to demonstrate their ability to apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline. It is now being rewritten ready for a first presentation in February 2016. This paper reviews the life of the current module; its structure, successes and lessons before looking at the options for its replacement, T452. The approach of the module is constructivist with an emphasis on reflective practice. However, there is little opportunity, either in terms of time or facilities for students to work together. Instead, the close participation of the tutor is intended to provide guidance as well as supporting the student. One element of the review is to address the solitude experienced by many students. This solitude is not autonomy and undermines the importance of interdependent learning.

Keywords: final year undergraduate projects; capstone engineering projects; open distance learning

1 Introduction

While it may be comprehensive to enumerate one hundred fears it would not be particularly interesting. So with apologies to Nobel laureate for literature, Gabriel Garcia Marquez, nine or 100 to base 3 should be sufficient and will, hopefully, be more illuminating! This paper will consider the feedback given by surveyed students, the reasons students fail their final assessment and the experience of the module team on the Open University's capstone project module for its BEng(Hons). It will identify and analyse the principal fears, weaknesses and underlying anxieties of students undertaking an academic project remotely. They will be placed in the context of project based learning and of the expectations of the different stakeholders in professional engineering higher education.

Then the current thinking on final year projects will be reviewed to define a strategic response to managing these fears. The paper will be completed by a set of recommendations to shape the successor module, T452

1.1 Brief history of technical project modules at the Open University (UK)

The UK's Open University (OU) has been presenting open supported distance learning since its establishment in 1969. Its first qualifications were the Open BA and BSc degrees which were awarded once a student achieved enough credits at the appropriate levels. With the introduction of named qualifications and the more recent changes in student funding in England, students now study set pathways. The OU follows the UK's Engineering Council's accreditation of HE programmes (AHEP)'s guidance first introduced in 2003 and now in its 3rd edition (The Engineering Council 2014) to evolve its BEng(Hons). It, too, is now in its third version, Q65 (introduced in 2012) with the previous ones B24 (2003-2014) and B65 (2010-2017). One constant in these degrees has been the Engineering Project, T450. This is a 30 credit (15 ECTS) individual project which is presented each February with the submission of the final report in September. It currently has 420 students registered.

T450 was based on the previous IT and Computing project (TM420-27) with its emphasis on the assessment of learning outcomes, reflective practice and supportive assessment. The principal learning outcome and the students' choice of topic are based on the modules they took prior to commencing the project. Its assessment strategy comes from the OU's commitment to feedback on learning outcomes and supportive assessment as described by Dillon et al (2005) and Gibbs (1999). Similarly the assignments and structure of the module were influenced by the eleven conditions defined by Gibbs and Simpson (2004). These are given in the table 1.

Table 1 Eleven conditions under which assessment supports student learning (Gibbs and Simpson 2004)

Quantity and distribution of student effort
1. Assessed tasks capture sufficient study time and effort
2. These tasks distribute student effort evenly across topics and weeks
Quality and level of student effort
3. These tasks engage students in productive learning activity
4. Assessment communicates clear and high expectations to students
Quantity and timing of feedback
5. Sufficient feedback is provided, both often enough and in enough detail
6. The feedback is provided quickly enough to be useful to students
Quality of feedback
7. Feedback focuses on learning rather than on marks or students themselves
8. Feedback is linked to the purpose of the assignment and to criteria
9. Feedback is understandable to students, given their sophistication
Student response to feedback
10. Feedback is received by students and attended to
11. Feedback is acted upon by students to improve their work or their learning

2 T450 The Final year project in the OU's BEng(Hons)

Final year projects, often referred to 'capstone', are seen as essential to the gaining of an undergraduate engineering degree. This broad view is well described by many stakeholders across the engineering world. From the US

Degree programs must provide a capstone or integrating experience that develops student competencies in applying both technical and non-technical skills in solving problems.

(ABET, 2012)

Or from the UK

Graduates are likely to have acquired some of this ability through involvement in individual and/or group design projects.

(Engineering Council 2014)

It was in this context that T450 was created. The student is required to have studied a suitable final year module from the range of fifteen past or present modules arranged in eleven themes. The principal learning outcomes being assessed are the demonstration of:

- an understanding of and ability to apply the relevant principles within the context of the body of knowledge appropriate to an honours degree level project
- the ability to integrate engineering knowledge across traditional academic boundaries

2.1 Composition of T450 cohorts

The OU's final stage BEng(Hons) Engineering project module, T450 is in its twelfth and final presentation. There have been approximately 2000 students who have registered for T450 since its first presentation. The completion rate has averaged around 85% with the overall pass rate of those completing at 90%. They have all been continuing students (ie they are experienced open distance learners) with the very great majority pursuing a BEng(Hons) qualification. T450 is the compulsory project for the BEng(Hons) and most students take it as their final module. The majority of students will have had higher education experience prior to joining the OU. This will normally be the UK's BTEC Higher qualifications like HNC ie stages lower than the final BEng(Hons) stage. However, the trend is for this percentage to be coming down with it now standing at 56%. The percentage of students with previous qualifications on entry to the OU lower than A level (ie not suitable for university entry) is at 11% and those with A levels or equivalent university entry qualifications at 33%. The reason for this trend is unclear but is unlikely to be related to the change in student funding in 2012. The percentage of female students hovers around 7% which is similar proportion as students who identify as Black and minority ethnic.

2.2 The Engineering Project (T450) experience

The OU surveys its students on a regular basis. These surveys are an essential part of the quality assurance process of a module. Students who have completed the module are asked 40 questions with a 5 point Likert scale for their responses. They are also asked to add comments, either general ones or in response to standard questions. For example,

What aspects of teaching materials, learning activities or assessment did you find not particularly helpful to your learning? We would welcome any further suggestions or comments to consider for future editions of the module.

The number of students who take the opportunity to respond is often small but both the answers and the comments are valuable. T450 has over the past two surveys had response rates of around 30%.

Reviewing these two surveys reveal the following a range of concerns. These have been grouped under the following headings in Table 2:

Table 2. Students' concerns

• Isolation	• Feeling stuck and directionless
• Lack of guidance	• Lack of understanding of the assessment
• Too much reflection on process	• Conflict with work expectations
• Uncertainty	

As the student numbers have grown then inevitably the number of students whose reports are adjudged as being unsatisfactory has also increased. For the 2014 presentation there were 37 end-of-module assessments out of 305 submissions which were failed. As these students are permitted to re-submit in the subsequent presentation, they require feedback on what faults/flaws their original report had. An individual report based on the feedback and assessment by the markers is sent to each resubmission student. From this feedback the following themes have been identified

Table 3. Students' weaknesses

• Unambitious projects attributed to fear of failure	• Lack of time
• Avoiding engagement with theoretical concepts and modelling	• Choosing projects to suit their workplace's aims and not theirs
• Poor project skills like literature review, planning and reviewing	• Lack of direction and drive

It can be seen that there are similarities and differences in the two lists. For example, the lack of direction appears in both lists. It shouldn't be expected that they would be the same as they are answers to different questions. Also while the subject groups overlap they are not the same. However, as the aim is to produce an improved version of the Engineering Project then the lists need to be synthesised. They can be listed under the following nine headings.

Table 4. Students' concerns and weaknesses

Lack of confidence	Uncertainty	Conflict of interest
Isolation	Fear of failure	Lack of project skills
Directionless	Too little time	Dislike of reflection

3 Review of the philosophy behind final year projects

The expectation that engineering undergraduates will undertake an individual project is widespread. In their paper on final year Engineering projects, Vitner and Rozenes (2009) give examples from South Africa, Spain, Singapore, the UK and the US before going on to describe their experience in Israel. They define the development of their work-based projects and how they manage the process of supporting students to define and execute their projects. They also discuss the monitoring and assessment of these diverse projects. From the Middle East, Al-Bahi et al (2014) describe the difficulties of presenting a suitably authentic context for final year, 'capstone' projects. However, there is a similarly wide variation in the form of project modules.

3.1 Project and Problem based learning

Endeavouring to find the differences between what we think of as project based learning and problem based learning is no straightforward task. At one end, there is the relatively simple distinction that Savin-Baden and Major (2004) propose, where project-based learning is more tutor led -students undertake structured tasks to a specific learning outcome and problem-based learning is more teams tackling open-ended problems. At the other extreme is the late Donald Woods' (2014) extensive detailed coding of different learning environments. He identified 32 which he analysed using different parameters such as degree of student empowerment; acquisition of knowledge and/or process skill; depth of knowledge. The learning environment which best suits T450 and includes both terms is the

Problem-driven research/inquiry or problem based synthesis or project based learning (problem used to synthesize previously learned knowledge and usually to develop process skill like critical thinking, or design: case method, inquiry, research or project-based learning. Often the solution to the problem is not known.

(Woods 2014)

Litzinger et al (2010), in an extensive paper on the development of Engineering Education and Expertise, look at the how students can practise the skills needed for the 21st century. They identify two key ideas from the work of others on expertise

The first is the importance of structuring knowledge in a domain around key concepts and principles of the field to facilitate students' abilities to access and transfer knowledge to new and novel situations.
The second is the central role of motivation in enhancing students' levels of performance in educational settings

(Litzinger et al 2010)

They go on to discuss the findings of Ambrose et al (2010) and Boshuizen (2009) which talk about the development of component skills and how to integrate them. The principal tension is that having the component skills does not necessarily mean that students can tackle complex tasks. It is this requirement to integrate different understandings and skills that makes project based learning (PBL) so attractive. Tempelman and Pilot (2011) reported how Delft University of Technology restructured their Design Bachelor programme so that technical theory wasn't left to 'happenstance' but was the 'cornerstone' of the practice. By having much more intensive practice based modules, they found that students' learning was significantly deeper. They concluded with three recommended principles when developing curriculum:

- Provide an authentic context

- Distinguish between knowledge, skills and attitude development and their synthesis
- Create a chain of meaningful activities interpreted reflectively

These principles are echoed by a number of other contributors to the subject of problem-based learning. Savin-Baden and Major (2004) identify the importance of Learning context, Learner identity, Transformational learning and Meaning construction to Problem based learning. They see that a safe, open and trusting environment is central to it where students can move towards autonomy.

If we synthesise the expectations of the programme, the professional engineering bodies and those of the students then there are some common themes but also some tensions. The accepted one is the opportunity to achieve deep learning, the sort that can sustain engineering graduates in their careers. A satisfying project should leave students with a sense of achievement as well as confidence that they have brought together the different elements of their undergraduate study. They should also have moved from the abstract to the particular and drawn justifiable conclusions. Their project management skills should have been tested and allowed them to tackle a problem multi-laterally. Savin-Baden and Major (2004) cite the work of Eva et al (1998) on the dimensions of a problem and the likelihood that students are able to transfer knowledge from one situation to another. They suggest that it is important to:

- Teach problem recognition
- Provide immediate feedback and guidance
- Emphasise the importance of problem solving as a valuable learning tool
- Provide numerous examples to demonstrate abstract principles

One aspect of problem/project based learning in engineering is an endeavour to 'mimic professional situations' (Stewart 2007). Generally, this is an attempt to provide authenticity as well as to introduce the multi-faceted characteristics of a real situation. T450, while looking to support actual projects, makes it clear that it is an academic project and so requires deliberate reflection and the achievement of learning outcomes.

4 Analysing the fears

The concerns listed above are still unwieldy so to enable a clearer view of them, they have been divided into three groups;

- ones that are ever present and need to be addressed by continual support
- ones that can be neutralised through advice and guidance
- ones which can be mitigated through teaching.

These distinctions should lead to proposals to include in the updated module, T452.

4.1 Fears to address

The Open University students are noted for their determination and perseverance and it is no different with the T450 students. In addition, there are some important characteristics that many engineering students share. Their aim is the BEng(Hons) so because T450 is a mandatory module, they are content to do it. However, they often don't have a solid desire to undertake an individual piece of work based on self-directed research. Reviewing the failures, it can be seen that the ones who struggle lack the research skills of literature evaluation and review. They often start the module believing they have them, so don't allocate time to learn or improve them. By the time they realise, they are then behind schedule and don't really catch up. Similarly they are often transfixed by a fear of failure. They have been conditioned by the OU's extensive support systems and find the unstructured nature of T450 challenging. With so much resting on the project, this raises the stakes significantly.

To improve these issues, the new module will provide much more structured teaching of research methods. Also since isolation is often the result of being pressurised but lacking direction, open student forums are promoted. The new module will encourage more participation, either in their tutor groups or in subject groupings. What is important to recognise is that these anxieties are part of the academic challenge. Students need to be supported through them.

4.2 Fears to neutralise

There is another group of fears which need to be designed out of the module. These can be characterised as being related to the students' personal situations. For example, a number of students will have their projects chosen or influenced by their employer. From one perspective, a project related to a pressing work-based problem is attractive. However, it rarely is. This is because the aims of an academic project often conflict with those of a work-based project. Furthermore, the schedules often clash. This conflict of interest can cause unnecessary stress for the student. Our advice is consistent in pointing out the pitfalls in this type of project. We need to strengthen this advice.

The other fear which affects a minority (but they are a vocal group) are those who dislike reflection. Much of this fear is caused by a lack of confidence in their capacity to make sense of the requirements. The assessment contains structured reflection and this needs more support for students to realise the benefits of it.

4.3 Fears to mitigate

These fears often manifest themselves in the tutor as well as the student. It can be seen in the lack of engagement that students have in their planning. Although they are specifically required to present a work breakdown structure of their projects along with a schedule early in the module, these are often poorly executed. This can be attributed to a lack of commitment and a misplaced sense of their own abilities. These can be mitigated by better and more explicit teaching of project management skills. Since the gaining of such skills is one of the principal learning outcomes, then the responsibility belongs to the module team. As more is being done in earlier modules of the qualification, it is expected that students will be better prepared to embark on an individual project.

5 Conclusion

What comes through most strongly in this review is that much of the responsibility lies with the module designers and programme managers. The changes required are throughout the module but disproportionately affect the early weeks of the module. By opening the moderated student forums well in advance of the module start then students can be encouraged to discuss their anxieties and queries together. It would also be a place for students to refresh their understanding of research and project skills. This will be in the form of structured activities with the Library systems and databases in particular. Similarly, with more access to information, advice and guidance (IAG) earlier in their project, then choosing the right subject at the optimum time should be more easily achievable.

One technically advanced improvement which will come with the new module is that all final project reports will be electronically available. It has been a regular request from new students to see previous years' reports. As they were all paper-based they were not easily available. The module team's view was that it was unhelpful to provide exemplars as they risked influencing students too strongly. However, if all were available in the form a digital library 'shelf' then students could sample and draw their own conclusions. This access to the look and feel of previous work would settle some anxieties without directing them away from using their own judgement.

The two remaining areas for strengthening are getting tutors to be more persistent in requesting and supporting student reflection. Many tutors already do this but more could be done. Similarly, tutors could be more consistent in using the learning outcomes as the focus for their feedback. As Gibbs (2010) remarks

However useful they are to course designers, students actually learn about goals and standards through a repeated cycle of practice and feedback, not through reading statements in their course guides

By using them at every stage, then their pedagogic purposes will become clearer and students will be able to respond to their advantage.

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Project-Based Learning approach for engineering curriculum design: faculty perceptions of an engineering school

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Abstract

The aim of this work is to analyse the perceptions of teachers, on a curricular change to a Project-Based Learning (PBL) approach, in an engineering school of Brazil. The PBL approach will be introduced in this new curriculum in the form of complementary activities to be performed by students. The activities will be selected by the students from a set of proposals elaborated by teachers and, in most of the cases, are not related directly with the disciplines of course. Some examples, can be workshops, like "motion and calculus", engineering projects, like "factory's project of skateboards" and engineering practices, like "Aerodynamics of buildings". The students have to fulfil a predetermined number of hours of these activities, up to the end of an academic year. The new curriculum will be implemented in the beginning of 2015, which implies an institutional planning and organization process from the teachers of this Engineering School. In this stage of the research just one dimension of analysis will be considered, the perceptions of teachers about what is PBL: its potentialities and constraints. As basis it is needed consider that this school is an environment which has more than fifty years of a traditional teaching approach, what makes interesting this study. The data collection was based in interviews in order to understand the concepts of interest, and the main teaching and learning approach used by them. The results reveal that the faculty team has an inaccurate conception about Project-Based Learning and has some concerns relating to the success of the proposal. About the genesis of the proposed curriculum, what is observed is the attempt to break with patterns of formation of engineers in Brazil, seeking an alternative approach that adds value to student and, at the same time, aligns the formation with professional practice requirements.

Keywords: Engineering Education; Project-Based Learning; Curriculum Development.

1 Introduction

The natural scientific and technological evolution poses new requirements from society and organizations that Higher Education Institutions (HEI) must cope with. One of the most important objectives of HEI is the formation of graduates able to meet these demands and also evolve to new stages of demands. The kind of change in teaching addressed in this work, relates with the need of a curricular redesign. The curriculum not only provides explicit activities related to the disciplines, but also the set of elements that define these disciplines, from objectives up to assessment tools, going through learning strategies that define the role of teacher and student. The curriculum is something planned, which will be implemented pointing intentions, the content to be taught and other aspects to its definition (Pacheco, 2005). A curricular reform also, as pointed out by Frenay et al (2007) and Oliveira (2007), is something that should be planned and structured, in advance and criteria, aimed at success. Considering this, a curricular change is always a challenge that can be even harder if the change is toward a curriculum with basis on innovative practices like active learning, in opposition of traditional strategies. This is a challenge that arises to the teachers with a special impact because in higher education, including in engineering schools, teachers do not have previous pedagogical training that could show them ways beyond the traditional teaching.

Considering that teachers are the main actors who will translate the ideal curriculum, to one that will be operationalized at school (Pacheco, 2005), it is important to know their previous conceptions. Thus, identifying the teacher's conceptions, about learning strategies and on a curricular reform that has as a guideline to use of active learning strategies, in particular the use of Project Based Learning (PBL) is very important, to propose necessary actions that could ensure a better chance of success in a curricular change.

The aim of this work is to understand the perceptions of teachers on the opportunity of use PBL in an Engineering School which is preparing for a curricular reform. The new curriculum will be implemented from February 2015, in the 1st year of engineering programs at the School of Engineering Mauá - EEM. The reform is being prepared since July 2013, involving a large group of teachers. This paper is an exploratory study using data collected in June and July of 2014, in the previous stage of the reform, from teachers who play an important role in the process of curricular change.

2 Background

The curriculum development involves three stages: preparation, implementation and evaluation. It's a building process that involves people and procedures. Built collectively, the curricular change is subject to the interpersonal dimensions, political, social and collaboration and cooperation. It is not just a rational scientific process, since the subjectivity is involved, nor sequenced or systematized. The subjective elements and its flexible nature, gives to curriculum design an open characteristic, different of design of a mechanism or a prototype (Pacheco, 2005).

Goodlad (1979) indicates that the start point of a curriculum begins with a formal proposal, called “ideal curriculum”, adopted by the school organization. Then there is the “formal curriculum”, which is revealed in the curriculum mediators, such as manuals and textbooks, and translates the official curriculum. A third step lies in the school educational project as a global training plan, is the “operational curriculum”, programmed by a group, and individually planned, "... what happens in daily practice and that compares to the official curriculum." Finally there is the “perceived curriculum”, experienced day-to-day at classroom. There is also the “evaluated curriculum”, which includes besides the assessment of students, curricular plans, programs, guidelines, manuals and textbooks, teachers, school, administration, etc.

By facing the difficulties in the training of new engineers, the Project-Based Learning (PBL) is an alternative, to traditional curriculum, that shows fertility not only to meet the specific technical training of these professionals, but also by promoting the learning of soft skills that are required in the labor market (Mesquita et al , 2013).

PBL is used in engineering courses and is premised on student involvement, actively with the object of learning, in an interdisciplinary way, to solve open problems (Kolmos, 1996; Lima et al, 2012). A "problem" is the starting point of a project and is the responsibility of students engage in the search for its solution. On PBL, teachers also have to develop communication skills and teaching strategies different from those of a traditional classroom (Mizukami, 1986).

Kolmos (1996) classifies different types of PBL: Assignment-based project - Project based in a part of a discipline; Subject Project - Project based on a complete discipline; Problem project - Design by open problem - Characterized by a problem and development of the learning process that goes beyond disciplinary boundaries.

Kolmos, De Graaff and Du (2009), present a model for detailed alignment of PBL with seven dimensions:

- Goals and knowledge;
- Types of problem, projects and classes;
- Progression, amplitude and duration;
- Students learning;
- Academic Staff and facilities;
- Physical space and organization;
- Student assessment and evaluation process.

The shift to PBL has been happening by some factors (Kolmos and De Graaff, 2007), as to decrease dropout rates; stimulate motivation for learning; enhance the institutional profile; support the development of new skills. The authors indicate that the extent of this change sometimes happens in a single discipline or in any structure of a course, which is something more complex.

About the process of changing to the PBL, Powell and Weenk (2003) point out three conditions for success:

1) Infrastructure - Facilities, training teacher and communication, this last to ensure a common basis about the perception and the need to change.
2) Authority - To ensure the planning, guided and progressive in an implementation accepted and institutionalized. With energy sharing, commitment and vision of teachers, on learning focused on students. This gives a bottom-up characteristic to the curricular project.
3) Consensus – It defines which problem is crucial for success of PBL and includes all direct stakeholders, on innovation process. The "cooperation between the teachers involved in PBL is just as essential as cooperation between students in their team (p. 124).

Cowdroy, Kingsland and Williams (2007), present a set of myths usually related to work with PBL, which have been dispelled by the engineering education community: one can only work with small groups; only technical subjects can be worked with PBL; means less time to work out the contents of the subjects and, consequently, lower level of learning; is simply coordinating study contents; is the nightmare in which all learning and problem solving should happen simultaneously; means leaving to evaluate objectively; means losing academic autonomy in content and methods.

3 Methodology

The main objective of this work is to understand the perceptions of teachers about the opportunity of use PBL in an engineering school in which, a new curriculum will be implemented. So, methodological approach is based on interviews with teachers who play an important role in the process of curriculum changes.

3.1 Context of the study

The Mauá Engineering School - EEM is part of the University Center of Technology Mauá Institute. It is a traditional engineering school, founded in 1961 and currently has more than 250 teachers and about 4,500 students. It offers nine engineering courses, with classes from February to December. They are annual courses in different specialties - Food, Civil, Computer, Mechatronic, Electrical, Electrotechnical, Mechanics, Industrial and Chemistry.

There is a curricular change that is taking place with the main guideline of increasing the use of Enrichment Activities, which will consist of workshops and projects undertaken by the students at the school, under the supervision of a teacher. These projects and workshops will be offered in the various curricular years of the course, starting at the 1st year in 2015, with gradual implementation in each subsequent curricular year. The Activities will be autonomous, not related with existing disciplines in the course, proposed by the teachers of school, regardless if they act in the series in which will be offered the projects.

The Curricular reform at EEM provides the transfer of hours of work in the classroom with traditional teaching strategies (Mizukami, 1986), to the Enrichment Activities, with learning strategies centered on the student, in which will be required of the student a more active attitude, collaborative and entrepreneurial.

The change proposed by the EEM direction has a top-down characteristic. According to Carvalho and Lima (2006) this is an important feature, because the institutional support is critical to the paradigm shift in the teaching-learning process. Structural changes like this one, involves reorganization of physical spaces, staff and organizational, impacting the entire institution and, without institutional support there is a risk not to take effect. The proposed new curriculum meets the National Curriculum Guidelines - DCNs to the MEC Engineering courses (2002), what means that the work by projects and the reduction of class time, it is desirable in the formation of the engineer.

3.2 Data collection and analysis

This research is an exploratory study, which aims to get prior knowledge of teachers about PBL, in a school that plan to adopt this strategy in its curriculum. This study is based on interviews conducted with seven teachers of EEM, all of them, coordinators and leaders of engineering course subjects. Six of these teachers are engineers and only one is from the area of Sciences, and six of them have never had experience working with the PBL. All respondents participated in at least one and, at maximum two workshops about PBL or Active Learning, offered by EEM, to them: "Project Based Learning", conducted in 2013, October; "Active and Collaborative Learning", and "Problem Based Learning", both conducted in 2014, January. All of these workshops had duration of 8 hours, in a day of week.

The interviews were conducted from a previous script that was not rigidly followed, characterizing then as a semi-structured interview (Lüdke and André, 1986). Were held during June and July 2014, recorded in audio with the consent of the interviewees and transcribed, to allow a more precise analysis of its contents. The transcript of the recordings was important to highlight the most common dimensions that emerged from all participants (Bardin, 2009). In that analysis the respondents were nominated from [Participant 1] to [Participant 7], without a relevant criterion for this numeration. These numbers appear in the analysis and discussion of the results, next of excerpt transcript of the speech to illustrate the results obtained, but preserving the anonymity of interviewed.

4 Findings

From the data analysis emerged five relevant dimensions used to discuss the perception of teachers about curriculum reform with the use of PBL. These dimensions can also be found in works related with evaluation process of Project-Based Learning (Lima et al, 2007; van Hattum-Janssen & Mesquita, 2011; Fernandes et al., 2012).

4.1 Meanings about Project-Based Learning

There is a good perception of the interviewed about the general characteristics of PBL. The duration of the project, the problem like a starting point, the problem like an open challenge and the autonomy of students to find solutions, are main characteristics pointed out. Although not all respondents uniformly express the PBL characteristics, the most general features are intelligible to all.

The projects developed are defined by open problems. Several interviewed refers that projects, bring within them open problems to be solved, what confirm the perception of some researchers (Kolmos, 1996; Lima et al, 2012).

> "*when one proposes projects to work actively, they think in problems that must be solved. The Project idea is to propose activities ... when we propose, we think on solutions to problems ...*" [Participant 4]
>
> The PBL the idea is "*to propose problems for students to solve ...*" [Participant 6]
>
> Projects must be "*enough open, like ... real problems, and sufficiently closed to they can finish*" what is the "*nature of engineering problems*" [Participant 1]

The general idea is in accordance with Kolmos (1996) classification of a Problem project, for which students should be able to develop a solution as the result.

About the student autonomy in solving problem, the PBL is identified as a strategy that allows the student solves problems. For example, to one participant the idea of PBL is:

> "*... to propose activities, to students 'to run after', alone, and be able to solve with guidance ...*" of a teacher. [Participant 4]

Duration of PBL's process, and the milestones. The project is identified as a process with duration and marked by milestones determine its stages.

> *"has a term a little bigger, a semester or a year".* [Participant 7]
>
> "*a route through time (with) beginning, middle and end*" [Participant 1]
>
> "*is something ... with steps ... associated to goals and guidelines that must be met".* [Participant 3]

All these features show a convergence between the views of the participants and the information specified by Kolmos, De Graaff and Du (2009), for the alignment of the PBL. However, the interdisciplinary activity which is a strong feature of PBL did not appear significantly in the interviews, which indicates a particular view of PBL.

4.2 Strengths and difficulties of student's learning using PBL

The main advantage identified by respondents in the PBL is to lead students to become **active** in the teaching learning (Kolmos, 1996; Lima et al, 2012), which is associated with **responsibility**, **maturity**, **pro-activity** and **better preparation for professional life**. As an example, this participant, said:

> *"I understand how a learning process in which you put the learner as an active participant and, in the learning process, you take the centralization of teacher and who goes (to be) the agent really is the student; either through problems or resolution of them, projects, you have an active student participation, so I think this is most interesting and motivating …. The responsibility acquired by student, the ripening, so prepare it better for working life, you have a more proactive person, more resilient."* [Participant 2]

The **commitment** and **dedication** appear associated to a better preparation to the student formulate and solve problems. More specifically four respondents indicate that students should learn to chase the content, with autonomy, identifying relevant content, being more critical and responsible by learning. Was remembered that being critical is something that just is acquired by the practice, from selection of what is or not important, which is favored by PBL.

> *"Gotta have this culture, the guy go after content, to know in which he has to invest more, so he can exercise criticism."* [Participant 1]

As **difficulties**, was cited that some students have a **passive** profile and are **immature**, what claims a paradigm change to work with PBL. These characteristics can hinder the work in PBL, so it requires guidance.

> *"they arrive with bad habits of high school, where all thing are being on hand, then it is a very big change of paradigm".* [Participant 4]

Another advantage associated with the PBL is the students **learn to work in teams**, what is pointed out by several authors about PBL (Kolmos, 1996; Lima et al, 2012). On the other hand the participant [7] argues that there are students with a particular profile, what should be considered in choice of PBL.

> "*... there are people who understand better sitting or noting, lowers his head and writes. You must also look into student's profile...*" [Participant 7]

About the **content**, the perception of respondents is that PBL allows the students are in contact with the same content as much as in traditional teaching, beyond this, affirms that the content's learning is greater given the **involvement** and **dedication**, and, because they are responsible on the contents (Kolmos, 1996).

> *"in terms of content, it will have more or less the same content, you will not be leaving to give content to the student,"* [Participant 6]

> "*learning is greater because (the students) becomes more involved and also more engaged*". [Participant 2]

Just one participant questioned if with PBL the students will have the same learning than in traditional education.

> *"I have the worry of what will be the quality of work. Because, in the traditional way the teacher will, gives the lesson, tests, students study, have the guarantee that he saw and is acquiring knowledge. When we do a project with a team, even small, has the problems of one student work more than the other."* [Participant 5]

4.3 The role of teachers in PBL

A non-traditional way to teach in PBL, and involve the students to turn them active in the process learning, is the main role assigned to teacher. To the respondents, the teacher's role in PBL is translated into different concepts:

> Facilitator: "*... directs, but tries to make student question himself, and go in search of solving the problem. He learns to formulate the problem.*" [Participant 1]

> Tutor: *"... because has a greater proximity of student, who is responsible for learning."* [Participant 2]

> Encourager: *"to say that the Work did not over, when the student find the result in the calculator and then ask 'what is that? Is It important? For what, you going to use it? He must have an orientation"*. [Participant 3]

Another interesting perception is that the teacher is also a learner with PBL:

> "...*I think people (teachers) don't realize the ability to be surprised ... it's a learning for (them)*..." [Participant 2]

All these roles assigned to the teachers are important and, at each times one of them stands. It is important, in a curricular design, the roles of the teacher as the other actors, be defined and shared (Pacheco, 2005), to ensure homogeneity and uniformity in its understanding.

4.4 Difficulties to the implementation of PBL

Some Difficulties are associated to PBL's Implementation. One is that some **teachers do not understand or do not believe on PBL**. This indicates the attachment to traditional education and little knowledge about PBL, is a drawback in their implementation. As quoted by Pacheco (2006) curriculum development is "*a process of construction that involves people and procedures*", so the involvement may help to a critical position to change. To participants [7] and [1] respectively:

> "... *(teachers) who does not believe in new things* ...". [Participant 7]

> "*we have several colleagues who should not even be aware of the curriculum reform, ... (and) don't be aware ... about what is PBL* ...". [Participant 1]

Another data related to difficulty of implementation of PBL is that **all teachers need to know the new curricular proposal**, its extent and challenges, to allow them to give feedback and collaborate to its construction. The projects that define the 'curricular design' need be made explicit and shared with all teachers (De Graaff and Du, 2009), to ensure the success of the proposal, from the consensus, as argue Powell and Weenk (2003).

> *" we have several colleagues who may not be aware of the curriculum reform, are aware of, but not taken part in the workshops and things".* [Participant 3]

The participant 7 point out that is need build instructional materials, because it help to know the horizon and the extension for the new curriculum, what imply to make clear the ideal curriculum by manuals and textbooks, what represent the operational curriculum.

> "*Generate thing for that? Generate materials for that, ok, do the proposed design. Yes, because you have to see whether it will be something more closed or more areas involved in the project*". [Participant 7]

The lack of projects maintained by the school is cited as another difficulty to Implementation of PBL. It was indicated that in other schools which use PBL there are many research projects, which facilitates its implementation. It seems that, at time of interview, there was no clarity on the new curriculum boundary conditions and, the new projects that will be offered. As a consequence, lack of consensus appears in doubts about infrastructure on the curriculum (Powell and Weenk, 2003):

> "... *the student has access to projects, companies and something more, ... I see that our reality is different but ... I see it is (possible) from the third and fourth year*". [Participant 4]

The large number of students in the classroom also is another difficulty pointed out on curricular PBL. Again, the lack of knowledge about curricular constraints could generate doubts and difficulty in this previous stage (Powell and Weenk, 2003).

> "... *the examples I have seen usually ... show the implementation of these methods in small classes*". [Participant 4]

4.5 Implications of PBL changes

Some elements brought by the interviewees are aligned to Powell and Weenk (2003) which indicate the infrastructure, authority and consensus as fundamental dimensions for successful curricular change to the PBL.

Infrastructure appears related to three elements: 1) **Tutors** to accompany the students; 2) **Classrooms with small number of students**, to allow follow-up work for students (Pacheco, 2005 and Powell and Weenk, 2003); 3) Adjust the school **facilities**, as classrooms, that allow work in teams (Powell and Weenk, 2003).

"for us to have a working active strategy we'll have to have a very well assembled structure tutoring to meet these persons". [Participant 1]

"The problem is the number of students in the classroom. I wanted to apply an active methodology, but to use this methodology, following the exercises developed in the room, I cannot be alone." [Participant 2]

"Classrooms in which there has more student participation. Physically our rooms allow this?" [Participant 5]

At **consensus** dimension, two elements are presented: 1) **Make public the new curricular structure**, and become aware the teachers on new path pointed. The teachers need to understand the ideal curriculum to may help to construct the formal curriculum (Pacheco, 2005), as already discussed; 2) **Training teachers to work with projects**, this was the most prominent element in the interviews. Overcome the accommodation and the teachers' resistance is a transitional step that requires time and strategies to attract and engage the teacher. This involvement goes through convince to accept the change of culture. Seminars and workshops on PBL are identified as important because it is necessary training and experience to make them more confident. The curricular change creates uncertainty and the need for cooperation, (Powell and Weenk, 2003).

"*... the change from traditional teaching centered on them (teachers) who control everything, (to another) into a PBL, leaves them completely confused. Because doesn't know what is going to happen in the classroom.*" [Participant 2]

"*... I think this thing also takes some of the fear, it helps a lot*". [Participant 4]

The **authority** appears on two elements: 1) **System monitoring and evaluation of the new curriculum**, considering the dimensions students, teachers and the project itself, as is quoted by Pacheco (2005). 2) **Institutional support** necessary to sustain the change, front the students and the teachers, what is indicated as important to success of change (Carvalho and Lima, 2006), and to support participants in change.

"To assess students and assess our project also." [Participant 5]

"*... we will get that support? ... Look, the teacher will have this support?* [Participant 7]

5 Final Remarks

The main objective of this work is to understand the perceptions of teachers about the opportunity of using Project-Based Learning in an engineering school in which, a new curriculum will be implemented. This research was carried from interviews with teachers who play an important role at school.

There is a common point of view among all participants about the PBL, although these concepts had not been expressed in a convergent form by all participants. The majority of conceptions can be found on literature. However, the interdisciplinarity, which is a strong feature of PBL, did not significantly appear in the teachers' perspectives. The Problem project (Kolmos, 1996), design by open problem, is the type o PBL that emerge from the data.

Several advantages in student learning were related to PBL as motivation, responsibility, maturity, proactivity and better preparation for professional life. However, the lack of background from high school was associated with difficulty to work with students using a Project Based Learning approach. On the role of the teacher, there is a list of assigned predicates that express different concepts, but all with the sense of supporting student learning. The no convergence of these concepts can be attributed the lack of sharing ideas about teacher's competences.

On the implementation of a curriculum by PBL, some difficulties were listed as the number of students per classroom, the accommodations to make the projects, the need to know and share the curriculum and the current number of existing projects in school, which maybe not is sufficient to meet all students.

In turn the actions necessary for the implementation of PBL are: tutors, classes with few students and suitable to work with the PBL. Furthermore: teacher training, institutional support, the sharing of idealized curriculum as well as the assessment of its implementation.

Although there are elements that deserve to be better worked as interdisciplinarity, teacher training and the student's role, to refine the understanding on learning process, the already established knowledge about PBL seems an important key to promote a change toward a new curriculum using PBL. Looking to the strengths and difficulties pointed by the participants Project Based Learning provides great opportunities for a curricular change. In turn, the difficulties must be seen as challenges in which institution, faculty and students need to face for innovation of teaching and learning process.. It is important consider that this group is small, with just seven teachers in a total of 250, but an expressive group with key teachers, that can contribute to conduct a curricular change.

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Developing Design and Professional Skills through Project-based Learning focused on the Grand Challenges for Engineering

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Abstract

In 2006, a highly respected international committee of engineers and scientists was formed to identify the Grand Challenges for Engineering of the 21st Century. Fourteen challenges were identified and announced including: make solar energy affordable, develop carbon sequestration methods, manage the nitrogen cycle, provide access to clean water, and engineer better medicines. At Lawrence Technological University three project-based learning (PBL) assignments have been implemented in first-year engineering design courses which promote awareness and interest in the Grand Challenges. Each project focuses on use of the engineering design process, technical engineering skill development, and practice of professional skills (e.g., communication, teamwork). One PBL involves the design, construction, and test of a vehicle that operates with a finite amount of rainwater, which connects to the challenge of clean water and importance of alternative forms of energy. The vehicle has size and water use constraints, must be made from repurposed materials, and must be optimized for distance and precision. The project encourages application of systems thinking to complex problems while students practice concepts in energy conversion. Another PBL focuses on a global problem involving cooking fuel and health concerns. Students design, build, and test a solar cooker using household items. Students learn the basics of heat transfer and how simple solar solutions improve health and address diminishing fuel supplies. A final PBL promotes recycling with students designing, building, and testing a three-stage beverage can processor. Requirements include size constraints, electric components, and specific fabrication techniques. This project requires students to apply systems thinking to a complex problem while promoting energy conservation and limiting natural resources depletion. This paper describes application of these projects and presents results of data collected from student surveys which indicate that the projects effectively promote use of the engineering design process as well as a variety of professional skills.

Keywords: project based learning, active learning; Grand Challenges for Engineering, first year engineering education

1 Introduction

In 2006, an international committee composed of some of the most accomplished engineers and scientists was formed by the U.S. National Academy of Engineering and the National Science Foundation to identify the Grand Challenges for Engineering (both problems and opportunities) of the 21st Century. The goal was to identify what needs to be accomplished to help people and the planet thrive. The committee received worldwide input from prominent engineers, scientists, and the public, and the conclusions were reviewed by more than 50 subject-matter experts. Fourteen challenges were identified and announced in 2008. The challenges include: make solar energy economical, provide energy from fusion, develop carbon sequestration methods, manage the nitrogen cycle, provide access to clean water, restore and improve urban infrastructure, advance health informatics, engineer better medicines, reverse-engineer the brain, prevent nuclear terror, secure cyberspace, enhance virtual reality, advance personalized learning, and engineer the tools of scientific discovery. Detailed information can be found at the Grand Challenges websites: www.engineeringchallenges.org and www.nae.edu/Projects/grand-challenges-project.aspx.

1.1 Motivation

A study has shown that design and computer application are the top two activities performed by engineers in industry (Burton, Parker, & LeBold, 1998). Other studies have shown that college graduates need a high level of communication and team skills; the ability to define problems, gather and evaluate information, and develop solutions; and the ability to use all of these to address problems in a complex real-world setting ("Quality," 1994). While most first year introduction to engineering courses focus on team-based design and complex problem solving, at the same time familiarizing the student with basic technical competencies, few also focus on professional skills required of engineers entering the workforce. In addition to teamwork, effective communication (written, verbal, and graphical), and computer application, professional skills including ethics and ethical decision-making, customer awareness, persistence, creativity, innovation, time management, critical thinking, global awareness, self-directed research, life-long learning, learning through failure, tolerance for ambiguity, and estimation are as important in the workforce as technical aptitude. In fact, a multitude of employer feedback has indicated that graduates with these skills are more highly sought than those with an overly technical education since technical engineering skills can be readily obtained on the job (American Society for Training and Development and U.S. Department of Labor, 1988; "Quality," 1994; Berrett, 2013; Fischer, 2013; Peter D. Hart, 2006; Maguire Associates, Inc., 2012). Professional skills on the other hand take years of practice/refinement. Although students may eventually begin practicing professional skills in the curriculum especially during a senior (capstone) project sequence, it is paramount that the importance of professional skills is stressed in the first year.

As the lines between engineering disciplines are becoming more blurry, employers also covet engineering graduates whose technical skills span a variety of disciplines. Engineers must work on teams that are diverse, and being able to understand and communicate the broad field of engineering is vital to success. Therefore, while completing an engineering degree, students need to become familiar with a multitude of engineering disciplines and work with students from many departments.

Based on the need to develop professional skills in an interdisciplinary setting, the College of Engineering at Lawrence Technological University in Southfield, Michigan U.S.A. requires all students to complete an interdisciplinary first year design studio course. The course emphasizes the practice of the engineering design process while integrating all of the professional skills listed in this section into well-established problem-based design projects, homework, and active learning classroom modules. A complete description of the course, its development, and its assessment can be found in Gerhart et al., 2014 and Gerhart & Fletcher 2011.

Many of today's engineering students are drawn to the profession by a passion to make a positive difference for society and the planet. In addition, it should be the responsibility of engineering educators to foster student interest in the social impact necessary by future engineers. Thus, a portion of the first year design course is devoted to the Grand Challenges for Engineering. This paper will describe application of three project-based learning (PBL) assignments which promote awareness and interest in select Grand Challenges. Each project contains learning outcomes associated with use of the engineering design process, technical engineering skill development, and the practice of professional skills.

2 Project-based Learning Associated with the Grand Challenges

This section will describe the organization and nature of the three team-based projects and present assessment results of data collected from student surveys measuring student perceptions of their application of the engineering design process, as well as use of and importance of teamwork, written and oral communication, computer aided design, and multi-component or multi-process (i.e., complex) design. (Unfortunately, data has not yet been collected for the other professional skills listed in Section 1.1.) For the surveys, students rated statements on a scale of 1 to 5, where 1 indicated "*no use*" or "*none*" and 5 indicated "*thorough implementation*" or "*highest importance*." Sample sizes range from 39 to 71. While direct assessment using instructors' rubrics to reveal the level at which the students are performing the skills has been completed, that data set is limited and thus not reported here. Additional direct assessment data will be needed to quantify skill level as opposed to skill use.

Note that during any given academic term, only one of these three projects has been deployed, because only a portion of the course focuses on the Grand Challenges. It is certainly possible to use all three of these projects within a single course, but time limitations due to the inclusion of other learning outcomes has precluded the authors from doing so.

While the students are carrying out the design project, each individual student is required to select any one of the Grand Challenges and write a research review and personal reflection paper. Elements of the paper include

(1) motivation including why the challenge is important to solve, (2) background and technical issues including limitations, obstacles, goals, and proposed solutions, (3) identification of which engineering disciplines could contribute to the solution and how they can each contribute, (4) identification of how the students' engineering major discipline could contribute to the solution, (5) personal reflection on the challenge selected including why it was selected, the motivation for selection, how they hope to contribute to the solution, and their feelings about the challenge and the assignment, and (6) references.

2.1 Engineering Design Process

Admittedly, there are many variations to the engineering design process (a review has been completed by Schubert, Jacobitz, & Kim, 2009), with some steps possibly occurring in parallel, and with some others being skipped altogether. The basic flow block diagram in Figure 1, however, outlines the fundamental sequence that is emphasized in Lawrence Tech's first year course. Within the first few class meetings, the diagram is distributed to and discussed with the students; in addition, some notes are also given to the students that explain what the process is, what purpose it serves, why it is useful, when to use it, where to use it, and briefly how to use it. For clarity throughout this paper, each step is numbered and abbreviated in the following way: 1) Define, 2) Brainstorm, 3) Design, 4) Build, 5) Test, 6) Assess, 7) Refine, 7.5) Retest/assess, 8) Report.

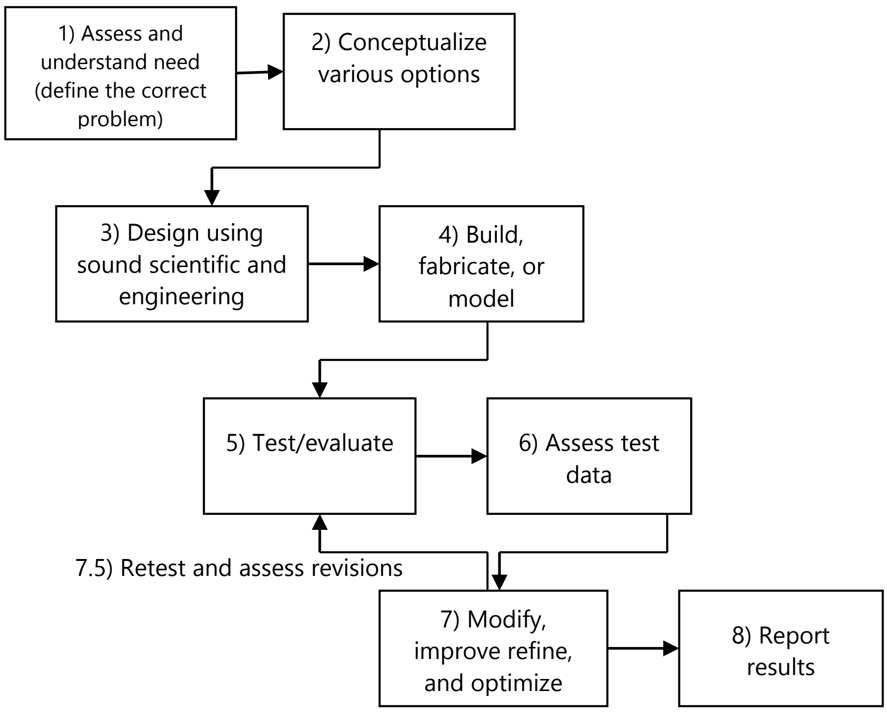

Figure 1: The Engineering Design Process used for projects in the First Year Engineering Design course

2.2 Water-powered vehicle

The water-powered vehicle is a relatively complex multi-component project which is best deployed after the first year students have acquired some design practice by completing at least one smaller-scale project (Gerhart et al., 2011). Teams comprised of three to five students are tasked to develop a small car that operates on a finite amount of "rainwater" (employing conversion of potential to kinetic energy). The project connects to the Grand Challenge of clean water, as well as the importance of alternative forms of energy. As stated in the student assignment hand-out,

> The potential energy of 1 inch of rainfall on the average single-story house, if captured at the roof height provides approximately 120 kJ of energy, and even more if the rain can be captured while in motion. Devices to convert and store this energy could be created, utilizing an untapped and readily

available energy source. In addition, the rainwater itself could be harvested and stored for a variety of everyday uses thereby conserving energy and precious fresh drinking water sources.

The vehicle must be no more than 18 inches (45.72 cm) long and 12 inches (30.48 cm) wide. They can use 0.5 liter of water with 60 cm height. The water must be captured and drainable (i.e., no water spills), and the student teams are only allowed to use repurposed materials (i.e., nothing bought new). Examples of rainwater cars are shown in Figure 2. The project is scaffolded (i.e., staged) over four weeks. Stages include 1) completing a worksheet defining the problem and determining a team schedule with a plan of action, 2) brainstorming and submitting multiple design ideas, 3) interim testing of vehicle, and 4) final testing and reporting. This timeline allows the students to focus on each step of the engineering design process, and points are awarded for the interim testing a week before final testing. This turned out to be an important aspect to emphasizing the importance of design steps 6 through 7.5, as well as applying systems thinking to complex problems. In general, most teams did not appreciate these important steps before the final (graded) test in class, but after faring worse than assumed, the student teams were much better at testing and refining their projects in subsequent projects. (Assessment results of the incremental gains in appreciating the engineering design process are given in detail in Gerhart & Fletcher, 2011 and Gerhart el al., 2014. Briefly, a significant difference in scoring (i.e., grade difference) between the two projects revealed that out of 40 teams, very few teams were able to reach their goals for the rainwater car assignment; five weeks later, completing another project, 39 of 40 teams achieved 45 of 45 testing points with many also accomplishing goals for bonus points.)

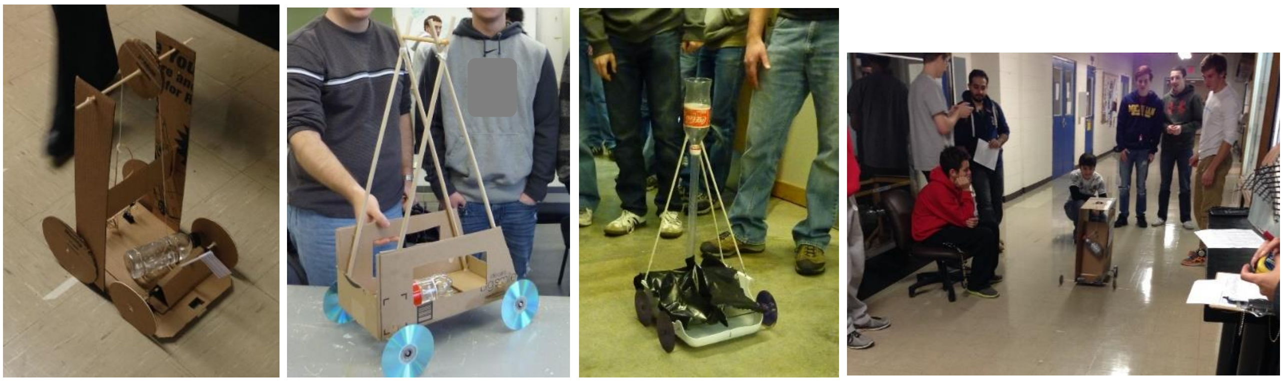

Figure 2: Examples of students' rainwater vehicles and a test run.

The students' car projects are judged on two tests. For the first test, the car is to obtain maximum distance; for the second test, the car must land on a specified mark ranging from 5 to 8 meters from the starting line (with the distance unknown until the test date). In other words, the object of the second run is to add sufficient water so that the car lands on the specified target. A score is calculated with the following formula:

$S = (D_1 - 100W_1 - O_1) - (\Delta_2 + 100W_2)$

where:

D = Distance car travelled (mm)

W = Water spilled over 25 mL (mL)

O = Distance off the centerline (mm)

Δ = Distance from the target (mm)

In addition to the design and testing, a written report is required wherein the students must clearly describe the process used to design, build, and test. In particular, the report includes key design features of the car, a brief description of how the engineering design process was used, changes made to the car design after the prototype testing, a description of the repurposed materials used so that the design can be replicated, and all sketches and drawings used during the project.

As indicated in Table 1, the engineering design process steps are "mostly" to "fully implemented" with two exceptions. As expected, the average is low for "assessing test data" (before the final in-class test). At this earlier stage of the course, students have had little to no experience assessing a design test. The lowest average is "report results." There are two possible explanations. First, even though the students were asked to specifically report on changes made to the car design after prototype testing, it is speculated that the students interpreted “report results” as reporting final in-class results, which was not possible since the report was due on the same day as the in-class test. Second, many teams assigned a single team member to write the report, so many students would rate this step low.

Regarding the professional skills, Table 1 displays a wide range of averages. Not surprisingly, oral presentation and computer use rank lowest; neither of these were required of the students, although it was hoped that students would perform some graphical design on the computer.

Table 1. Students’ ratings of statements after completion of the Water-powered vehicle

Skill	Average	Median	Standard deviation
1. Assess and understand the need (define the correct problem)	4.33	4	0.65
2. Conceptualize various options	4.35	4	0.72
3. Design using sound scientific and engineering principles	3.96	4	0.85
4. Build, fabricate, or model	4.36	5	0.81
5. Test/evaluate (before in-class test)	3.97	4.5	1.15
6. Assess test data	3.83	4	1.07
7. Modify, improve, refine, and optimize design	4.36	4.5	0.81
7.5. Test and assess revised design	4.07	4	1.08
8. Report results	3.60	4	1.11
Importance of teamwork for this project	4.47	5	0.71
Practiced teamwork	4.06	4	0.95
Importance of written communication skills for this project	3.42	3	0.96
Practiced written communication skills for this project	3.23	3	0.85
Importance of formal oral presentation skills for this project	2.33	2	1.16
Practiced formal oral presentation skills for this project	2.19	2	1.18
Used the computer (not including note-taking or communication such as email) as a tool for the design, testing, and/or, evaluation	2.42	2	1.32
Practiced the design and fabrication of a multi-component project	3.72	4	1.10
Practiced the design and fabrication of a multi-process project	3.63	4	1.13

2.3 Solar cooker

The solar cooker project emphasizes problem solving for a global issue involving cooking fuel and health concerns. This project can be deployed in ten days or up to four weeks depending on the learning outcomes or level of depth desired. The project consists of multiple stages. For the first stage, the students, working in pairs or occasionally in threes, watch a very brief slide show where the students are introduced to the problems associated with cooking in countries whose population has minimal economic means and insufficient power supply. Briefly the students are introduced to the following:

> Over one-third of the world’s population relies on wood, dried animal dung, crop residues, or charcoal for domestic energy needs including indoor cooking. Many problems are related to this issue: the problem of long journeys to collect fuel (which leads to missed schooling and further eroding their economic status), excess time spent cooking (mostly by the women), the health issues associated with smoke inhalation (1.6 million die each year from cooking fuel smoke), etc.

The problem statement is then given to the students: “What can be done to address this issue and thereby alleviate extreme poverty, improve education, promote gender equality, reduce child mortality, improve health, and promote environmental sustainability?”. Depending on the duration of the project, the students are given either 24 hours or one week to prepare a response which includes a list of possible solutions and expanded detail on the best solution in the list. During the subsequent class period, the students and instructor discuss some of the solutions and whether or not they solve the problem. As it turns out, there is only one good solution: a solar cooker. Each team is then tasked to design, build, and test a solar oven, which must be able to purify water and cook food for an individual family or small group. Note that for testing purposes, the designs should be able to contain a dial-gage (oven) thermometer inside of a small cooking pan placed inside of a sealed cooking bag. Each team is required to submit:

- evidence that their oven meets specifications
- a functional prototype of the oven
- originally created design specifications and plans that allow someone to construct a replica oven
- detailed cost to reproduce the oven if it was mass produced by hand using readily available materials
- a deployment plan for which region/country will receive the ovens.
- a final report conforming to specific guidelines

The teams are allowed to use designs that are readily available on the internet at sites such as solarcooking.wikia.com/wiki/Category:Solar_cooker_plans and www.re-energy.ca/docs/solaroven-cp.pdf. Examples of solar ovens are shown in Figure 3.

Figure 3. Examples of student teams’ solar ovens. The students do not work in teams of four as implied by the photos.

It is also possible to frame the project with a real-world business scenario. An example of a problem statement follows:

> A non-profit organization (The Carpenter Foundation) is awarding two $100,000 grants for the best solar oven design that can be easily replicated and distributed in third-world nations. Your design team is challenged with winning that award and improving living conditions in a country/region of your choice. Each team will create a 15-minute presentation using PowerPoint to “sell” their design. The presentation should include a distribution plan (including country or region), and details on how the money will be spent (e.g., project overhead, training, production, shipping, etc.).

Besides practice of the engineering design process and professional skills, learning objectives can include topics of sustainability and ethical obligations of engineers. The students also gain some experience with technical skill development. After the ovens have been tested a presentation detailing the modes of heat transfer as related to the solar cookers is reviewed and discussed. This information can be supplied before the design process begins or the students can be allowed their own self-discovery (as is typical in project-based learning).

Unless the students are designing a new, original cooker, there are many steps of the engineering design process that are unnecessary, so the goal here is not to use each step of the process. Instead the students need to perform thorough research to carefully pick the best design (i.e., best use of the modes of heat transfer) that can be built within the limited time frame. They also must practice careful construction techniques to maximize reflection and optimize direction to ensure proper heat absorption. (A well-built solar oven made mostly of aluminum foil and cardboard will easily reach temperatures over 230ºC (450ºF) on a clear sunny day, even in cold winter weather.) Therefore the results of teamwork, using the computer for research, and engineering design steps 2 through 4 are pertinent. Assessment data is only available for the 10 day version of this project, wherein oral and written communication results were not applicable. Table 2 reveals the engineering design steps 2 through 4 at a level of 4 or higher, as is desired for a project in the middle of the academic term. Despite limited knowledge of heat transfer, the students attempted to use scientific and engineering principles in their design. Also from Table 2, the students appear to be achieving a significant level of teamwork, and are mostly implementing the computer as a research tool for their design, albeit with a high standard deviation. It has been concluded that some students leave the computer research to their teammate(s).

Table 2. Students' ratings of statements after completion of the Solar Cooker Project

Skill	Average	Median	Standard deviation
2. Conceptualize various options	3.94	4	1.05
3. Design using sound scientific and engineering principles	3.92	4	0.93
4. Build, fabricate, or model	4.44	5	0.82
Importance of teamwork for this project.	3.97	4	0.90
Practiced teamwork	4.38	5	1.18
Used the computer (not including note-taking or communication such as email) as a tool for the design, testing, and/or, evaluation	3.46	4	1.48

2.4 Beverage can processor

The beverage can processor project emphasizes energy conservation and limiting natural resources depletion by promoting recycling. During the introduction to the project, students are informed that recycling aluminum uses about 5 percent of the energy that is required to extract aluminum from natural sources and produces less than 5 percent of the emissions. Furthermore, only about half of all aluminum cans are recycled in the U.S. For successful completion, the project requires the use of all of the engineering skills introduced, and compared to the prior projects entails a significant amount of team coordination. Students, assembled in teams of three or four, design a three component beverage can processor consisting of a can dispenser, a can crusher, and a crushed can transporter/bagger. Each component must fit within given size constraints. The can dispenser must accept five cans in the vertical position, transport each can vertically and horizontally, and dispense each can individually in the horizontal position to the crusher. The crusher must flatten the can to 1.5 inches maximum, and eject the crushed can at a 90º angle from where it was introduced. Finally the transporter must move the crushed can 36 inches with an electrically powered drive mechanism to deliver the cans into a plastic grocery bag. In addition, students must use specific fabrication techniques for both metal and wood components, and must incorporate electrical lighting (LED preferred). (The students are required to be trained in the use of the University's metal and wood shops.) Examples are shown in Figure 4. Just before in-class testing, the students present a "pitch" reviewing highlights and unique features to "sell" their idea to the instructor. After testing, the students submit a formal, distinctly formatted written report with computer generated schematics. Consequently, all of the professional skills are important to success of this project: use of the entire engineering design process, effective teamwork, oral and written communication, using the computer as an engineering tool, and multi-component fabrication and processes.

Figure 4. Examples of student-designed beverage can processors.

The project is staged over the course of five weeks. The initial stage requires problem definition and various sketches of multiple ideas. Next a scale model (made of cardboard, foam, and other inexpensive supplies) must be demonstrated in class. Next individual components are trial tested. One week before final testing, all of the components are tested and calibrated in tandem. The final week entails the pitch, graded test, and submission of the written report.

Table 3 reveals high student ratings for all skills with one unsurprising exception. Formal oral presentation is not rated highly; while the students are asked to give a brief "pitch" prior to testing, they are not required to give a formal presentation. The purpose here was to "sell" the design quickly by only pointing out its unique features.

Table 3. Students' ratings of statements after completion of the Beverage Can Processor project

Skill	Average	Median	Standard deviation
1. Assess and understand the need (define the correct problem)	4.52	5	0.57
2. Conceptualize various options	4.40	5	0.82
3. Design using sound scientific and engineering principles	4.05	4	0.91
4. Build, fabricate, or model	4.60	5	0.59
5. Test/evaluate (before in-class test)	4.16	4	1.01
6. Assess test data	4.09	4	0.90
7. Modify, improve, refine, and optimize design	4.34	4	0.69
7.5. Test and assess revised design	4.21	4	0.97
8. Report results	4.05	4	0.97
Importance of teamwork for this project	4.60	5	0.65
Practiced teamwork	4.05	4	0.91
Importance of written communication skills for this project	3.96	4	0.87
Practiced written communication skills for this project	3.79	4	0.96
Importance of formal oral presentation skills for this project	4.09	4	1.02
Practiced formal oral presentation skills for this project	3.56	4	1.27
Used the computer (not including note-taking or communication such as email) as a tool for the design, testing, and/or, evaluation	4.07	4	1.08
Practiced the design and fabrication of a multi-component project	4.47	5	0.76
Practiced the design and fabrication of a multi-process project	4.40	5	0.82

3 Conclusion

Three project-based learning assignments relevant to the Grand Challenges for Engineering have been deployed in a first year engineering course. The projects are intended for practice of the design process and select professional skills deemed of high importance in the profession of engineering. Student surveys revealed their use these skills. Assessment of the data indicates that the students are using the skills that are relevant to the project at a high level. In addition, they deem some of the those skills as important to the success of the project. Further studies with direct assessment will be needed to quantify skill level as opposed to skill use.

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Project Based Engineering School: Evaluation of its implementation. Students' Perception

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Abstract

The School of Engineering at Universidad Europea de Madrid (UEM) implemented, starting at the 2012-2013 period, a unified academic model based on project-based learning (PBL) as the methodology used throughout the entire School. This model expects that every year, in each grade, all the students should participate in a capstone project integrating the contents and competencies of several courses. This paper presents an evaluation of its implantation from the students point of view. The results are encouraging as students are more motivated and the initial set objectives were accomplished.

Keywords: project based learning; student's motivation; learning process.

1 Introduction

The high level of abstraction and the large theoretical workload inherent to engineering degrees using lecture based teaching has been connected with low student motivation and high rates of student dropout (Devadoss and Foltz 1996). Under the EHEA (European Higher Education Area) approach proposed by the Bologna Declaration, faculty members of the Engineering degrees of the Universidad Europea de Madrid decided to implement in their classrooms some new active teaching and learning methods and strategies (Terrón López and García García 2010, Fernández Santander, et al. 2012, Terrón López, García García y Blanco Archilla 2009). Teaching methods were therefore centred in the students.

Spencer and Spencer (2008) stand that 'the better the fit between the requirements of a job and the competences of a person, the higher the person's job performance and job satisfaction will be'. Recent surveys to employers (Association of American Colleges & Universities, 2013) say that they seek for students prepared for success as workers and citizens in the 21st century. This means that they have to develop personal and professional skills including sustainability, problem solving and decision-making as well as technical competences, teamwork, leadership and communication. In particular some of the accreditation approaches for engineering programs such as , the European Accreditation of Engineering Programs (EUR-ACE®), as well as the Accreditation Board of Engineering and Technology (ABET) stand that they have to demonstrate that their graduates acquire the industry desired skills and qualities in the future. This demand for engineering professionals is characterised by requirements of deep and solid interdisciplinary technical competences and communication and management skills (Chandrasekaran, Stojcevski, Littlefair, & Joordens, 2012). Changing Engineering programmes to meet these requirements can be addressed by different active learning methodologies centred in the students such as problem-based or project-based learning (Mills & Treagust, 2003). To integrate into the curricula projects to provide a specific solution to a problem allows students to apply and integrate knowledge from several subjects while developing competences such as teamwork, communication skills and time management (Land & Zembal-Saul, 2003; Dopplet, 2003). Using projects as engineers do in their profession, students learn to make interdisciplinary connections between what they have learnt and the application of this knowledge. That is why several institutions of higher education have been addressing project approaches to engineering education. Using PBL students apply knowledge and techniques of different subjects to a project making interdisciplinary connections between them and developing, in parallel, engineers competences (Helle, Tynjälä, Olkinuora, & Lonka, 2007; Lima, Carvalho, Flores, & Van Hattum-Janssen, 2007; Hilnoven & Ovaska, 2010).

As a consequence, in 2012 to apply a Project Based Learning methodology was decided in the Polytechnic School of the Universidad Europea de Madrid (UEM). Starting at the 2012-2013 period to build a Project Based

Engineering School (PBES) applying this methodology throughout the entire School was decided (Gaya López, et al., 2014). Some good experiences that helped the implementation of our Project Based Engineering School (PBES) can be found in the literature: Aalborg University, Monash University, Central Queensland Universitu are some examples among others.

1.1 Context

To implement a Project Based Engineer School was the aim of the School of Engineering of the Universidad Europea de Madrid in the 2012-13 academic year (Gaya López, et al., 2014). The objectives of this *Project-Based Engineering School (PBES)* were to:

- Increase motivation and pride of belonging of students and teachers.
- Obtain a deeper learning.
- Develop and promote key skills.
- Bring the classroom close to the profession.
- Focus on social, economic and environmental sustainability.
- Encourage entrepreneurship, technological innovation and internationality.

During the projects development, teachers must guide their students in order to ensure deep learning, generating a greater satisfaction with their studies. Additionally, the participation of real companies should increase the motivation in our students to lifelong learning. This will help to achieve higher levels of employability, since the companies are participating in the training of future employees Additional consequences of the implementation of this model are the greater involvement of students in university life, the support of the university through mentors in developing emotional intelligence of its students, and the increase in the students of an interest in innovation. All this process can be seen in figure 1.

Figure 1: Academic Model of the Project Based Engineering School (PBES)

The School of Engineering at the Universidad Europea de Madrid (UEM) offers degrees in four fields of study: Information and Communications Technology (ICT), Industrial, Aerospace and Civil Engineering. The strategy is to offer every student at least one engineering capstone project per year in which the knowledge developed through various courses converges and it is used for the design and development of one integrating project. Although not all subjects are directly involved in the projects, the rest is replacing traditional blackboard classes using active learning strategies instead, i.e. flipped classroom, collaborative work, etc. (Velasco Quintana & Castilla Cebrián, 2013; Terrón López & García García, 2010).

After its first year of implementation we detected as one of the biggest benefits to increase the relationship of the UEM with local companies (Terrón López et al., 2015). The integration between companies and the university means that professionals in those companies are aware of the solid training received by our students. This connection may result in an increase in the employability of our students.

During the 2013-2014 academic year the scope of engineering degrees and schedules remained but, as we can see in figure 2, the number of projects was increased by 10, thereby having more courses (101) and teachers involved (66) in the PBES. Also the number of capstone projects that were done in or for a company was increased substantially. During 2014-15 the data are very similar to the previous year.

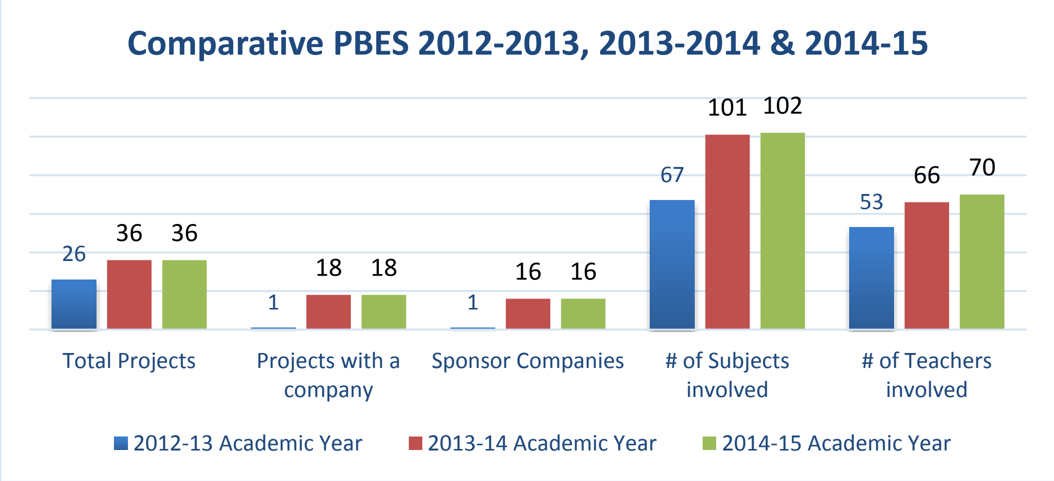

Figure 2. Comparison of the results of PBES implementation between academic years

As this paper is written by one of the students participating in the PBES as a student and as a researcher, the objectives of this paper are to evaluate the current state of implementation of the PBES from the students' point of view, to promote particular actions of improvement.

2 Methodology

At the end of each academic year, data were collected through an online survey for the students and teachers that took part in the projects. This survey finished with three open ended questions: what was the best in this methodology?, what was the worst?, how will you improve it?. Likewise, semi-structured interviews (Kvale, 2014) with an academic supervisor and several students were conducted on the following dimensions: deeper learning experiences; skills development; student motivation; sustainability; strengths and limitations of the PBES implementation; doubts and difficulties and ways of overcoming them; suggestions of improvement. The purpose was to measure the accomplishment of the objectives.

Overall, 228 students responded to the survey during 2012-13 and 2013-14 academic years, representing a 58% return rate. A representative group of each degree was invited to participate in a semistructure interview (we don't still have data from the 2014-15 academic year). The general topics covered by the interviews were the objectives of the PBES, although some other topics emerged during them.

The resultant data from both sources was analysed using a mixed qualitative-quantitative methodology. The quantitative data were processed by performing a statistical study and had been presented elsewhere (Terrón López, García García, Gaya López, Velasco Quintana, & Escribano Otero, 2015). The qualitative data was analysed by content through coding and interpretative analysis techniques, generating different categories of description in relation to the objectives of the project. We present in this paper the results of the qualitative analysis because of its richness (Berg, 2004) to explore the extent to which students are comfortable with this 'learning by doing' methodology.

3 Students' perception

We present here the students perceptions from the categories emerged from the qualitative analysis of the open ended questions and the semistructure interviews. The final category structure corresponds to a system based on the global objectives sought to design and implement the PBES. Once these main categories identified, we proceeded to its division into several subcategories. This division was varied throughout the analysis. References were added and the structure of the categories was reviewed. Therefore the main categories that emerged were: Motivation and pride of belonging; Deeper learning; Key skills development; Closeness to the profession; Sustainability; Encourage technological innovation; Other perceptions.

As subcategories we looked for positive, neutral or negative references. As we will see, in general, students' perceptions regarding to the implementation of the project based engineering school are positive.

3.1 Motivation and pride of belonging

To learn using projects emerged in the interviews as a factor that increased the students' motivation as well as their pride of belonging to the Universidad Europea de Madrid. A 70% of the coded references were positive, 21 % negatives and 9% neutral. Students compare their motivation when there was not this methodology implemented in the School with the actual year:

> *'Compared to the previous year, I would say yes, my motivation is greater because in addition to learning in a different way, due to the constant practice, you develop healthy competition when you see others can manage to do it and you don't. Therefore, you try to study every day on your own and you want to go to classes. You ask about doubts you have and that enhances your motivation. It is much more stressing at the end but you are motivated and you do want to come to classes to keep learning and to say, "Ah, I want to do it as that group has done it." It is much more motivating than without it.'*

They also compare this type of projects with other smaller ones that they have done previously, linking motivation to both learning and struggling with solving a bigger problem:

> *'To me, personally, a bigger project motivates me much more than a small thing like a button that does a little thing. It is a real thing that has a beginning, a purpose and a functionality. You feel overwhelmed at the beginning and say "Oh, what a big thing I have to do!" but little by little going to class that is where we set out the project, at home where we have to progress and see how to do. Little by little thanks to classes, classmates, or even by self-initiative you start to see the light, finding the way and so… That seems to be a very, very positive aspect to me… The thing is that it is really cool!, to see how you start to get the project off the ground and little by little you are learning and so.'*

3.2 Deeper learning

Students referred they have achieved a deeper learning with the PBL methodology, being a 95% of the coded references positive and a 5% negatives. They see the project as something which challenges them to learn rather than to just merely study:

> *'Yes I have learnt more, much more. I have gone from studying in order to pass, to study in order to learn, that the mark will eventually follow. It is very important, not only because I have improved my marks but because the concept has changed; it is not the same when you study to pass an exam than when what matters to you is to learn in order to get the project off the ground. When you finish, then you, inside, know much more and that for the future is the most important, in my opinion.'*

In addition, they consider that they do not only learn more but in fact they retain that knowledge better:

> *'Learning without a clear example it is easier for you to forget what you are learning, whereas if you are doing it yourself in a real project then you retain more.'*

> *'The project is the way in which you learn best. You truly have a linearity, each day you learn a bit more. With an exam you learn in one go at the end and then you forget it. With the project since you have to apply what you are learning, you learn much more.'*

3.3 Key skills development

Students also highlighted that they have learned other competences important to their future profession such as how to communicate (using project writing and presenting their own work to others), to manage a team and planning among others. 71% of the coded references about this category were positive while 29% were negatives. Teamwork, autonomous learning and responsibility were the key skills mainly coded.

Teamwork was the one with more references. Students compare the project with other practical exercises done in groups stating that within a big project teamwork is better developed:

> *'You have to distinguish between practical exercises and the project. In practical exercises you divide the tasks and each member of the group is in charge of his/her part and then you unite. In fact you do not learn to work in a team. In a larger group you have to plan because if not the project will fail. You have to know which tasks each member can do, and everyone has to be in the know because if not there are people that cannot continue with the project. When there is someone that doesn't follow, you have to help him/her and it gets complicated. In this sense you develop it more in the*

project; in practical exercises you don't get to plan neither to work as much as a team, you only divide tasks and distribute them.'

On the other hand, the students complained about the main problems that emerged within their teams. The principal conflict that appeared in many cases was regarding the individual team members that didn't work:

'You have to coordinate from the beginning. You have to help your mates and be very careful so that what happened to […] doesn't happen to you. It also happened to me, you think that everybody is going to do his/her work and at the end you find yourself the last day having to do it all by your own because if not you will fail too. You have to anticipate and be alert for those things. If in two weeks you already see that the team doesn't respond, you have to take decisions: help them or warn them.'

In addition to teamwork, many students also highlighted the development of autonomous learning:

'Concerning self-learning: the project implies knowing things that, although you don't study them to have a 10 in the exam, things do come out, problems start to set out that then will appear later. For example, when we started this project, at the beginning we didn't have a clue about how to do a web application, but classmates with experience tell you things, you start looking,… and then when the time comes to do the design you have to learn things that you will re-learn or go in depth later on.'

Responsibility was the third skill with more references, especially in the positive sense:

'I think the project helps a lot with responsibility. Since you are working always on the same thing, you must be up-to-date or at least you shouldn't be too delayed, whereas when you work with many different activities, if you do not do one of them, you will do the next one, it won't matter.'

3.4 Closeness to the profession

Another important aspect that students have pointed out is the relationship that exists between the projects they have made and their future professional careers. Concerning this, a distinction is made between those references linking the content of the project to the profession, in which a 90% of the references were positive, 2% negatives and 8% neutral; and those references about the collaboration of companies in the projects, in which 79% of the references were positive and 21% negative.

With respect to the references linking the content of the project to the profession, the students believe that the project has helped them to be better prepared for their future:

'It has been a really interesting experience to live through. Knowing what we are going to deal with in the near future is a very good way to prepare ourselves for what is to come. We have faced real-life situations which will allow us to perform our jobs better and that is extra experience when entering the world of work.'

'I think it's that, that it introduces you directly into that world… into what you are going to do in that subject. Because it is not the same that someone explains to you: ok, a road has to be X km long; than that you really start to design a road with the regulation in your hands, which is what you will find when you come out of university. To me, that is the most important aspect.'

The students also enjoyed performing a real-life-based project:

'Yes because I prefer to do a project about how I think the aircraft of 2040 will be, why and how it would be, than doing a presentation about topic 4 of propulsion, which are the typical presentations and projects that are done; presentations about something from the subject of materials, for example we did a presentation about thermoplastics […] it doesn't have as much to do as the design of the aircraft of 2040 which can interest you more because I think it is more real than a presentation about that.'

Regarding the collaboration of external companies, some students thought that problems about intellectual property and other legal aspects could arise, but generally they believe it was a positive experience:

– Academic supervisor: 'In one of the first interviews with [the company] the resentment came out that, if the project finally had the enough quality, [the company] could "take advantage" of the work done by the students. How do you feel with respect to this problem?'

– Student: 'If finally [the company] got benefit from the project, I would try to see it as the best letter of introduction in the future when the time comes to entering the professional world: "I have done this, and this company, which is real, is

profiting with it". If part of that benefit corresponds to us by right or not, are legal issues which I do not have much knowledge about and, as a student, it wouldn't matter much to me.'

Moreover, the students whose project didn't involve an external company see it as a great opportunity:

'In addition they come and they tell you the first day, this company, a man comes to you and tells you, "we want this, this and this" and if besides that if they tell you maybe we are going to give to the best one a pen-drive or a pin or whatever, then you go like more motivated. And if moreover you think for yourself, that if I stand out I may be able to go in. Although they don't tell you, the thing is that it works that way. Or even if you cannot go in, the thing is that then you are going to have an internship interview and you can say, look, I have participated in this…'

3.5 Sustainability

In general, students have reflect about economic, social and/or environmental sustainability while developing their projects (60% of the coded references said so), but we find that 24% of the references stay that they haven't done (while in 16% of the references we find they don't know). We should stress than some of them think that thanks to these projects they have been concerned about issues regarding sustainability:

'This project helps you consider issues that wouldn't be developed in any other way.'

'[…] as the subject goes by and they explain you things, you start to see why something would be like this and not in another way, and you include it in the project […] so they explain you things and you say "ok, I have to take this into account when…".'

3.6 Encourage technological innovation

With respect to technological innovation, all the references state that the projects have mainly encouraged the students to develop new ideas for their future:

'Yes, that it has a purpose not clearly academic in the sense that you present that, but instead you have an idea that then can be good, it can help you with the rest of your career and even your future.'

3.7 Other perceptions

Apart from the perceptions based on the global objectives sought to design and implement the PBES, the students also noted other interesting aspects, some of which were frequently mentioned. Between the positive additional perceptions, the students highly valued feeling useful and being capable of making things while doing the project:

'By the time the quarter ends, and you are not stressed out anymore you end up liking it and you say, "Look, I did that and the window that opens my code" When you manage to make it work, you are proud of yourself and you say, "Do you want me to show you the project I did at the university? In the end, it is something good indeed and it holds the course together. It does not feel like a dead end. It brings the quarter to a continuum.'

They also appreciated the support received from some of the teachers involved in the projects:

'[…] for example in the part of thermodynamics we had like small weekly deliveries and after presenting it we had a feedback, so we always knew where to head and then of course that could be seen in the final result.'

An interesting point to mention was that students felt more aware of their degree thanks to the project:

'It is very important to be aware of the knowledge you are acquiring and to see which functions you can perform in the future. During the freshman and sophomore years in any major program, you study things you usually do not find useful. That is why most students are stuck in the first years. […] There are times when students don't know exactly what is it they are studying but until their third year in college. Now, by having this kind of graphic interface project during our first year, things become real. If you do not find that motivating, then that means you may be studying the wrong major.'

In addition, the projects provided a global vision of the different subjects to the students:

'Moreover you can relate some subjects with others; you don't just centre in what can be done in one subject. You say, look, with this I have learnt this, but in addition I can associate it with this subject, and with this one and this one.'

Yet, not all perceptions were positive, and several negative aspects from the project arose. The most repeated complaint was regarding the distribution of the workload:

'It should be better distributed. There is too much workload of PBL and too much of exam, being insufficient the time available for the students to develop both, being prejudicial to the latter.'

'What I liked the least is the stress at the end of the project. The project has to be better organized in order to give it continuity instead of being "do it in the last two weeks and let's see what you can manage to do".'

Linked to this, the students also mentioned the negative effect of the coincidence of the project's deadline with the exam dates:

'The deadline of the projects should be better selected so that it doesn't overlap with the exams, due to the weight that such projects tend to have, both in the sense of weight in the final grade as well as theory to present.'

Another highly repeated negative aspect, was regarding the bad organization of the projects:

'The desperation for spending hours, hours and hours without obtaining any result until you became aware. This is also due to the bad management of the topics explained in the subject itself, since most of the things that had to be applied were explained weeks later in class.'

Moreover, the students said they didn't have enough information about the project, about what had to be done, and this impacted negatively on their motivation:

'In one of the subjects they didn't explain us anything about what we had to do and that puts us off attending to class due to not knowing how to perform the work, and to work by my own I prefer to work at home.'

Apart from the lack of information, some of them attract attention to the lack of knowledge required to do the projects:

'I understand that it is important to develop these competencies, but we are at the university, what no one can think is that with simple notes we will be capable of performing projects of such magnitude.'

4 Results and conclusions

After processing the student's perception data from the 2012-2013 and 2013-14 academic year we have noticed that most of the students agree that doing the project has motivated them. It has helped the students understand and know the contents of the subjects better. Students have perceived that they have acquired more skills they will need in their profession. This, together with the closeness to the professional world, has influenced positively in their motivation.

In general, students' perceptions regarding to the implementation of the project based engineering school are positive. They have also perceived an improvement in their academic performance and as a result their satisfaction with the academy has risen.

However, the bad organization and distribution of the workload, as well as problems with the teams for the projects are issues that have impacted negatively on their motivation. It seems that if the time of making the project is too busy or too short, it can decrease students' motivation instead of increasing it.

From these results next year project will be designed considering some aspects as:

- Trying to make a better coordination between teachers providing them some coordination tools.
- To get an active participation of all the faculty even if their subjects are not involved in an integrating project.
- Increase industry participation and terms of this participation.
- Review workload related to each project making projects charts.

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Complementing the engineering degrees with a volunteer program abroad: a different PBL experience?

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Abstract

In January 2013 the Polytechnic School of the Universidad Europea de Madrid (UEM) in collaboration with the Cerro Verde Foundation (FCV) started a volunteerism project where students and teachers are involved to provide technical support to the projects that this foundation has in the community of Cerro Verde (Choluteca, Honduras). The projects included five areas of development: water and sanitation Project; electricity supply; health and education. It is in this context where some students of the Universidad Europea de Madrid, work in order to complete their final project degree developing sustainability competences as well as multiculturality skills. Students participating in the project have to collect technical and legal information and documentation, that is, all the data needed to develop the project while travelling there. During the month of July they travel there with two teachers in order to evaluate the situation. During this month they collect the data needed for their project as well as determining other project that could be done in the area. Students and teachers are guested in the village. We present here how, involving students with this kind of multidisciplinary projects, allows students to develop important key skills as engineers and as more active global citizens.

Keywords: volunteer programs; sustainability; project service learning.

1 Introduction

In 2009 an interdisciplinary group of faculty members of the Universidad Europea de Madrid starts a project on Sustainable Development (SD) and volunteering in Ethiopia to provide technical support to NGOs and / or foundations, from the fields of medicine, architecture and Engineering. These projects are consolidated in 2011 with a Project of Inter-University Collaboration between Addis Ababa University and the Universidad Europea de Madrid (Universidad Europea de Madrid and Addis Adaba University, 2011). This project was funded by the Spanish Agency for International Development Cooperation (AECID), for making hydrogeology projects in areas with major deficiencies of water. The aim was to ensure water supply and to improve distribution network and sanitation, consolidating and establishing benchmarks for providing and promoting sustainable development of populations. This project was conceived to encourage student participation and to facilitate them the possibility of carrying out their final degree project in real contexts, working with disadvantaged populations. Specifically 7 students (2 from Physiotherapy, 2 from TIC and 3 from Civil Engineering areas were involved.

Subsequently, in January 2013, the Polytechnic School of the Universidad Europea de Madrid (UEM), in collaboration with the Cerro Verde Foundation (FCV) initiated a new volunteer project where students and teachers provide technical support to projects that this foundation has in the community of Cerro Verde (Choluteca, Honduras). This technical support is done in the classroom, through projects developed in the subjects, and then through teachers and students moving to Honduras where they will live with the people of Cerro Verde apart from developing a project.

We present in this paper the experience of students and teachers involved in this volunteer program that complements the developed project-based learning (PBL) in classrooms (Blanco Archilla, Gaya López, & Bernaldo Pérez, 2013; Universidad Europea de Madrid, 2014). The lived experience there can also be considered as a service learning (SL) experience of our students that have traveled to the community and have become part of it during the month of July.

2 Context and objectives

During 2012/2013 academic year, the Polytechnic School of the Universidad Europea de Madrid (UEM) started its "Project Based Engineering School" (PBES) (Terrón López, García García, Gaya López, Velasco Quitana, & Escribano Otero, 2015). This consists on the application of the Project-Based Learning (PBL) methodology in all its degrees organizing the students learning around some projects (Thomas, Mergendoller, & Michaelson, 1999; Thomas J. W., 2000). The students have to develop, in each academic year, a comprehensive project covering partially the content of several subjects. Different teachers were involved in each project developed.

In January 2013 the Polytechnic School of the Universidad Europea de Madrid (UEM) in collaboration with the Cerro Verde Foundation (FCV) started a volunteerism project where students and teachers are involved to provide technical support to the projects that this foundation has in the community of Cerro Verde (Choluteca, Honduras). Cerro Verde is inhabited by a number of families (around 500 people) who live in small houses rudimentarily built, which do not have any kind of hygienic-sanitary installation, nor any regular supply. The projects included five areas of development: water and sanitation Project; electricity supply; health and education.

It is in this context where some teachers and students of the Universidad Europea de Madrid start to work with the Cerro Verde Foundation. We introduce some of the projects in the classrooms and offered students to travel to Cerro Verde to implement what they had done at the university in order to develop sustainability competences as well as multiculturality skills and their social and human relations skills among others (Blanco Archilla, 2012; Blanco Archilla, Gaya López, & Bernaldo Pérez, 2013). In that way, we were using the academic context into real-life situations that will make students, make some reflections about their future profession. This way of learning through projects will follow Kolb's model which requires a learning cycle where the learner experiences, reflects among its observation thinks and acts (Kolb, 1984).

Students participating in the project have to collect technical and legal information and documentation. That is all the data needed to develop the project while travelling there. During the month of July they travel there with two teachers in order to evaluate the situation. During this month they collect the data needed for their project as well as determining other project that could be done in the area.

Students and teachers are guested in the village. What we want with this is to find some tools that improve the students' learning with other activities developed in collaboration with other agents of the local community of Cerro Verde, as it could be done with Service-Learning. Service-Learning (SL) is a proposal which emerges from the volunteer service to the community and from skills acquisition, combining them in a single articulated project (Coyle, Jamieson, & Oakes, 2005). We believe that making contact with the villagers and their way of life allows us to tailor specific projects to reality in the area and live the experience as it was our community. Students will use their engineering knowledge and interact with the local community to observe their needs and reflect on social issues. Projects can be implemented by the students over an extended period as they are proposed by the NGO.

Figure 1: Some of the participants in Cerro Verde

3 Description of the work done

In January 2013, led and organised by the Polytechnic School as a Project Based Engineering School (PBES) the teachers in charge of the volunteerisms project realized a meeting to explain to the faculty the needs of the NGO Cerro Verde Foundation to integrate their needs into the subjects using the PBL methodology. The need was projects including five areas of development: water and sanitation; electricity supply; health and education. From this meeting some integrating projects between several subjects and degrees were thought to be developed in the areas of ICT, civil engineering, architecture and mechanical and electrical engineering. During the month of March, they students were invited to travel to Honduras to develop what they had been working in their classrooms opening this activity to students of different degrees such as health.

The process followed can be shown in figure 2.

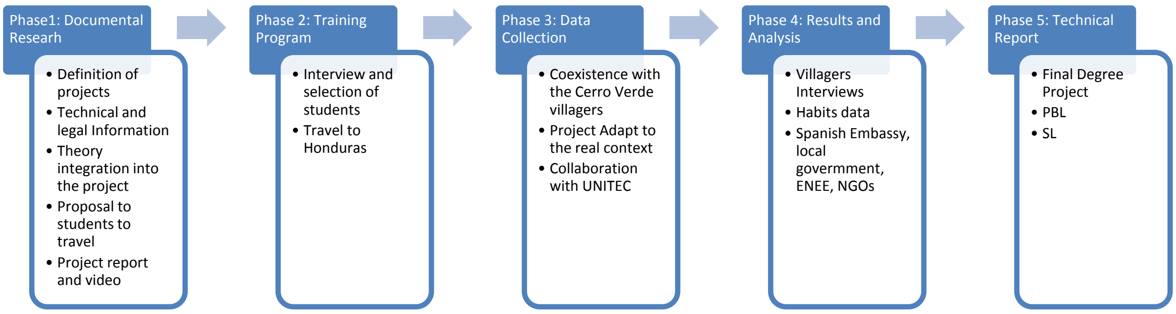

Figure 2: Scheme of the cooperation process from UEM with FCV in Choluteca, Honduras

3.1 Phase 1

Teachers, together with members of FCV, made a previous trip to the work area to evaluate the area, look for accommodation, knowledge for the environment and study needs. In this visit institutional contacts were done with the mayor of Choluteca, the delegation of the state power grid company (ENEE), different NGOs and Foundations, and, of course, the Spanish embassy and the Spanish cooperation agency. These contacts led to a very significant the development of the project in the classrooms before going there, as well as a further better development. We also contacted UNITEC (University of Honduras). The collaboration between universities in industrialized countries and poor countries is well documented (Sharma, Thapa, Johansen, Dahlhaug, & Stoa, 2014).

The definition of the projects that could be done was determined by preliminary proceedings begun by the FCV, and the role of the university was to provide technical support. The projects where we decided to working with our students were:

- Catchment, distribution and regulation of drinking water and development of a sanitation system by studying optimal latrine system tailored to the needs of the population and awareness of its importance.
- Development of the electrical network.
- Enlargement of the School favoring the development of education in the community, as well as training on hygiene, cleaning, health and responsible use of water and electricity.
- Study of the health system in the region.
- Study of the local architecture to provide improvements for the installation of the electrical network and the extraction of fumes from the kitchen by installing chimneys.

Once we knew the projects they were presented to students in their classrooms. Students were from different degrees and subjects from the areas of health, Mechanical and Electrical Engineering, ITC, Architecture and Civil Engineering.

This initial phase involves a process of documental research collecting all the technical and legal information and documentation necessary for the development of proposed projects. Studying all this documentation and integrating the theory learnt in the classroom will give the students the supposed best solution for the projects. This meant that students from different degrees developed in their classrooms (integrated in their curricular subjects) some activities as:

- Analysis of the existing network of water supply points, losses, water quality, needs of the population and inventory on the consumption liters / person / day.
- Evaluation of water catchment needs. Approximate flow rates for the new network.
- Pumping tests performed in the two water wells.
- Water analysis. Setting the frequency of water analysis.
- Installation of water storage tanks and purification.
- Design of the new water distribution network.
- Project for installation of sensors inside the wells for periodic analysis of water quality.
- Study on the state of latrines and their uses.
- Topographical study for the design of the new supply network and the power grid.
- Study of the possibility of making reservoirs for rainwater harvesting.
- Writing a recommendations tender to ensure the use of latrines and optimize existing ones.
- Design and execution of latrines.
- Study of a photovoltaic electrification project.
- Study of a grid extension and dimensioning.
- Assessment of current status of houses for installing the electricity grid.
- Economic evaluation of the cost of energy for the population and sustainability of the facility.
- Analysis of the materials used for the construction of houses and suggestions for improvements.
- Study of the typologies of dwellings in the village. Deficiencies. Improvements proposals.
- Design of chimneys for smoke extraction kitchens. Execution of prototype.
- Analysis of the needs of the educational system of the village.
- Project to extend the school.
- Study of the health system in the region.

Students have to write a report for their teacher and make a video explaining the project developed. One of these results can be in the university web page (Universidad Europea de Madrid, 2014).

During this phase students are invited to travel to Honduras to implement the projects developed. Students interested in going to Cerro Verde are then interviewed in a selection process (phase 2).

3.2 Phase 2

After the students' selection process was done by the teachers involved, a training program about volunteerism and international stays was taught to the students travelling to Honduras. This program provided them some country orientation, emphasized on specific context on cultures, and gave them some health and safety issues needed.

We have to remember that the stay in Cerro Verde involves a number of difficulties that students are not used to, as is the lack of water and light, high temperatures, presence of insects, very limited public transport. These situations determine very significantly the methodology and, of course, generate an exercise of reflection on the existence of other realities very different from their own one and, therefore, about the world in which they live and, in turn, allows the development of key skills both as professionals, and as global citizens.

Working from social commitment, with the most disadvantaged, from what we do in a university, which is to provide our knowledge, brings us to a broader and responsible vision of our role as professionals in the case of teachers and as future professionals in the case of students.

Teachers and students traveled there during the month of July to Cerro Verde (Honduras) in order to evaluate the projects that can be made and to collect of all the data required by each project to continue during the next academic year. Coexistence with the Cerro Verde villagers in order to better adapt each project to the real context was the first setback they had to face. Then a study of the specific area conditions where they will develop the project was needed. The help given by UNITEC with the data was very important at this stage.

The total number of students involved (July 2013 and July 2014) has been 22 from the areas of health, Mechanical and Electrical Engineering, ITC, Architecture and Civil Engineering.

The total number of students involved has been 22 from the areas of health, Mechanical and Electrical Engineering, ITC, Architecture and Civil engineering.

3.3 Phase 3

During their stay, students must write a technical report with the data collected explaining all the work done.

With all of this data the FCV, the students and the teachers agree the most appropriate projects for the needs of the population of Cerro Verde (final project degree, PBL, SL).

This report contains not only technical data but also a personal diary where students write their personal experience about what they have lived. These personal diaries were collected by the teachers. Students didn't write their name on them, but an acronym, so they felt free of writing their own feelings.

The technical data weren't only the ones needed for the engineering project but also some interviews teachers and students made to the villagers in order to gather their needs.

This data collection involved a visit to all the houses in the village and to talk to a large number of neighbors. On this tour, they took some cards to complete the information corresponding to water consumption, hygiene, number of people living in the house, number of rooms, house conditions, and type of housing and representative photos. Besides these visits offered the opportunity to meet the concerns of the population, their fears and their problems and create a framework of trust and closeness between students, teachers and villagers. It is important to consider the culture shock that implies this volunteering and the emotional implications for all, villagers and university students and teachers. It is important to stress that teachers and students have stayed in the villagers homes allowing closeness to the reality of the village and generating a great admiration by the government of Choluteca and the Spanish embassy.

3.4 Phase 4

With all the data collected students wrote a technical report. Some of them were the ones that were going to be used as a starting point in the next academic year. Others were also their final project degree.

4 Reflection about the experience

With these projects we wanted to facilitate teachers and student not only the experience of working in real world projects but to facilitate them a volunteer international experience as a way to develop competences linked to Education for Sustainable Development. These real world projects and living leave students with a deeper impression than learning merely in their classrooms.

As explained before, to collect the lived experience, students were asked to write a diary with an acronym if they wanted. These diaries were qualitatively analyzed because of its richness (Berg, 2004). Some coding and interpretative analysis technique was used to do it.

From this analysis we have found that the experience has led to goals related to the academic / professional education and to values education such as:

- Critical thinking: Critical contextualization of knowledge by establishing relationships with global social, economic and environmental problems, local, and / or global.
- Responsibility: sustainable use of resources and the prevention of negative impacts on the natural and social environment.
- Relationships and decision making: participation in community processes that promote sustainability.
- Awareness of ethical values: application of ethical principles related to the values of sustainability in personal and professional behavior.

- Global mindset: Willingness to promote diversity, openness and respect for other cultures, working effectively with people of different cultures, styles and skills, making optimal use of their views and ideas for meeting goals.

Some of these findings can be found in J. Peris et al. (2015) or in Fernández-Sánchez et al. (2015).

The learning process that takes place in this kind of programs encourages inquiry, create, experiment, adjust and self-assess the process lived. It generates an approach to their professional future problems as well as the ability to relate the contents and applications and resolving issues that arise in an area which, as mentioned throughout this paper, presents additional difficulties result from the living conditions of the village where it was developed. The final result is that the contents of the subjects are no longer isolated elements but they have a direct correlation with reality. Moreover, as the team is interdisciplinary, you can establish the relationship of learning objectives with other areas of knowledge.

> I think that really all the students need the chance to take part in some volunteer work. There are so much differences between what I learnt in the classroom and what I have seen here! We made designs in Spain and now, in real-life I have to consider the conditions of the village and make adjustments of our work. We had made a perfect planning! And… we have had to re-adjust everything. So, what I have learnt is…. So much! Not only I had to relate all the subjects but I had to lead with people. Std4

On the other hand, this distance between what it is learnt in the classroom and what they found in the field became a trouble sometimes.

> I think there is some things that should be improved…For instance, to inform better about the projects we were going to develop here […] if someone has explain me better what I would have had here I would have invest more time in other parts of the project.
>
> Std1

For instance they saw the relationship between the distribution of drinking water and creating some kind of sanitation to avoid diseases. This involved civil engineers and health students as some diseases occur as a result of the consumption of untreated water or contaminated by fecal due to the lack treatment of wastewater.

> I learn a lot being with heath students. They know so many things I don't! Std9

Another purpose of this project is to improve the living conditions of the village. In this way the student is an active subject, committed to the development of social commitment and empathy, and the ability to guide reflective processes.

> I wanted to understand the feeling of the villagers. […] I encountered so many things that were out of my expectations! I didn't want to leave Std1

A problem that was detected is the complexity of living together in such a different environment than usual one. They had to live without light, water scarcity and away from the family circle and friends, unable to use the Whats App or the internet.

> I am missing my friends. I miss my family. I wish I could send them a what's app. Std3

5 Conclusions

We consider that this project has great potential as a learning process of the student, given the actual context in which it is developed, adapted to the needs of a community and their life conditions to preserve the sustainable development of the community.

There is a clear contribution of each of the participants in this project in development principles proposed by the Cerro Verde Foundation through a cooperative, responsible and ethical work, with a participation that involves intense personal experiences in a hostile environment in relation to the habitual way of life and work of students and teachers.

The development of this type of initiative proposes a framework for exceptional work, where it joins the work on real projects by students who develop skills to implement the knowledge acquired in the classroom in a different environment, with difficult access resources and poor working conditions.

The multidisciplinary nature of the project generates an overview of the actions that each student performs in their area of expertise, fostering a global contextualization of the work performed and the idea of convergence of each performance as well as the transfer of knowledge.

In the diary written by the students, it is revealed the extent to which the competences are developed and their degree of satisfaction with the learning process.

For the Cerro Verde Foundation (FCV) the participation of the University in this project mean to open a field of action a very specific volunteering. It gives a support that facilitates data collection and a detailed analysis of the previous situation of the village and the changes they have been operating.

Local organizations have received with admiration and gratitude that students and teachers from a Spanish university move to their village to live with its citizens and to participate in projects that FCV is developing.

These academic activities related to development cooperation involve a major advance in current approaches to Education for Development and Sustainability within the European Higher Education Area.

These initiatives require institutional support for their development and implementation in all areas of knowledge and, thus, to involve more students.

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Prototyping as the completion of a Problem Oriented Project Based Learning approach: a case study

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Abstract

Graduates in Industrial Organisation Engineering develop their professional activity in a wide range of positions of responsibility within the organisation; indeed, they lead teams which encourage the participation and involvement of people to tackle the strategic challenges of organisations. Besides, although it is a managerial degree, these graduates should be able to do competitive and sustainable industrial activities and services, promoting the improvement and innovation of products, services and technological processes as well as organisational models. Due to this fact, the rapprochement between the Industrial Organisation Engineering students and the final product or service is essential. In this line, the present article provides evidences of how the Industrial Organisations Engineering Degree from the Engineering Faculty of Mondragon University has solved the previous gap using the Problem Oriented Project Based Learning (onwards POPBL) as the mechanism for engaging Industrial Organisation Engineering students with the final product or service. Indeed, the main characteristic of this approach is the integration of a last stage: the prototyping. Students are asked to develop a draft version of a product or service that allows them to explore their ideas and show the intention behind a feature or the overall design concept to users. Thereby, students are encouraged to work through problem situations, generating possible solutions and testing these against personal experience and the prototype. Concretely, this paper explores the use of the prototyping, within the POPBL approach, with the third course of Industrial Organisation Engineering Degree. The method employed was a case study design using observation as the main data collection technique.

Keywords: problem oriented project based learning; active learning; engineering education; prototyping.

1 Introduction

There is a growing need for graduates to apply their knowledge and skills in project oriented working environments (Moore & Voltmer, 2003; Traylor, Heer, & Fiez, 2003), thus it is increasingly necessary to include these practices as an integral part of its formation activities (Domblesky, 2009).

The conditions of a problem and its potential solutions, both, could be conditioned by the complex context where it is located. Due to this fact, the possible ways for solving a problem rarely are transferable from one context to another. This situation makes the development of personal qualities essential, both individually and in group, for the conceptualization of the problem, the recognition, the generation of solution strategies and the implementation (Errasti, Igartua, & Zabaleta, 2013). Moreover, it is really important to get the problem as close as possible to the student's future work context (Burdewick, 2003).

According to Burdewick (2003), and based on previous studies, there is no agreement on the content and structure of the problem oriented project based learning (onwards, POPBL). However, there are four aspects to be considered in a POPBL approach: autonomy at work, the importance of practicality, personal skill development (so-called soft skills) and cooperation between the university and external agents which introduce practical aspects to the project. In addition to these skills, the POPBL is developed in order to complete students' transversal competencies such as: team work, effective communication and decision making, among others (Zubizarreta & Altuna, 2009); which will be useful for their future careers (Domblesky, 2009).

Regarding the POPBL, various factors are taken into account: the learning outcomes, the contents, the student teams and the teaching staff, and the physical, material and time resources (Zubizarreta & Altuna, 2009). Moreover, it is also important to side the project evaluation method with the objectives of each POPBL project and to establish the development of something physical (such as a prototype) to be evaluated (Proulx, 2004).

This last characteristic of the POPBL, the development of something physical, is really important for the students of the Bachelor's Degree in Engineering in Industrial Organisations; since, although it is a managerial degree, these students should be able to do competitive and sustainable industrial activities and services, promoting the improvement and innovation of products, services and technological processes as well as organisational models.

From this base, the present paper describes the last POPBL (the POPBL 6) of the Bachelor's Degree in Engineering in Industrial Organisations which aims is to work on the technical and economic viability of an identified potential business opportunity; reaching a prototype. This approach has been developed with two consecutive groups (academic course 2012-2013 and 2013-2014) and the methodology employed was a case study design using observation as the main data collection technique.

2 POPBL approach at Bachelor's Degree in Engineering in Industrial Organisations

The students from the Bachelor's Degree in Engineering in Industrial Organisations from the Engineering Faculty of Mondragon University, in addition to a classroom training that enables them to acquire specific technical competences, develop a total of 6 POPBL project through their academic training (one per each semester). These projects are really helpful for the future graduates, since they will develop their professional activity in a wide range of positions of responsibility within the organisation; indeed, they will lead teams which encourage the participation and involvement of people to tackle the strategic challenges of organisations.

The duration of these POPBL projects varies depending on the academic year; specifically, first year students spend four weeks developing the project, second year students five weeks and finally third year students six weeks. During these weeks, the students move forward from the statement of the problem and progress in the project through different stages. Table 2 shows the objective of each POPBL from the Bachelor's Degree in Engineering in Industrial Organisations from the Engineering Faculty of Mondragon University.

Table 2 Description of the POPBLs

Academic Course	Semester	Objective
1º	1	POPBL 1 - Analysis of the operations, design and materials of a climbing nut in order to compare their behaviour in a crash situation.
	2	POPBL 2 - Analysis of a "XY" model to ensure its inclusion in the products catalogue, ensuring that the model is able to travel the distance "d" at time "t".
2º	1	POPBL 3 – Designing the manufacturing process and the plant lay-out of an aluminium wheel rim in order to reduce cars' emissions.
	2	POPBL 4 - Redesign a generator to respond to the market requirements and the impending competition.
3º	1	POPBL 5 - Design of a proposal for transcontinental transport of tanks for cooling milk.
	2	POPBL 6 – Technical and economic viability of a potential business opportunity identified from fields such as: sport, leisure and health, sustainability and rural development or energy and health.

In the POPBL development period, students work in teams of 5 or 6 people and they have the support of a tutor (this tutor belong to the teachers' group of the semester) who ensures the proper development of the project and the effective functioning of the group. Besides, there is an expert for each knowledge area involve in the project who provide the technical support to the students. Thus, despite they work autonomously, students have the support and the involvement of the teaching staff through the whole project.

3 Case study: prototyping as the completion of the POPBL approach

In order to clarify the application of the prototyping as the completion of the POPBL approach, the case study is divided into 5 different sections; as it has been shown in Val et al. (2006). The first describes the application context in which the POPBL approach is applied. The second section is based on describing the didactic method. Afterwards, the different agents involved in the approach are defined. In the fourth section the POPBL developed through the second semester of the third course on the Bachelor's Degree in Engineering in Industrial Organisation is described. And finally, the evaluation system applied is shown.

3.1 The application context

The application context of the POPBL methodology within the Engineering Faculty of Mondragon University and in the field of prototyping has been focused on the Bachelor's Degree in Engineering in Industrial Organisations. Concretely, on the POPBL 6, which aim is to analyse the technical and economic viability of a potential business opportunity; developing its prototype. Therefore, the project is based on three phases, which correspond to three major milestones arises:

- Defining the problem; the aim is to limit the problem, the market, competition rules, etc.
- Finding the solution; the aim is to define different approaches / alternatives to solve the problem objectively selecting one with which he will continue.
- Solution approach; the aim of this latest milestone is to carry out the selected solution, defining the expected results and developing the prototype.

In addition, there are 7 different subjects involved within the POPBL and specific learning outcomes are established for each subject (see Table 3). It is worth to be highlighted the last subject called POPBL, since this is not a real subject. Actually, this subject is used in order to measure the transversal skill acquired within the project, such as: the final report format, the prototype and the final presentation.

Table 3 Subjects involved in the POPBL 6 and its consecutive learning outcomes

Subject	Learning outcomes
PROJECT MANAGEMENT	Plan, organise and manage projects.
	Know the basic problem of new product launches and identify appropriate performance modes for proper planning and management.
MARKETING	Develop a marketing plan.
ECONOMIC ENGINEERING	Perform the approach of an investment project and develop its economic and financial evaluation.
INFORMATION SYSTEMS	Recognize the potential of Information Systems / Information Technology and Communications for the management of a company.
	Integrating Information Systems / Information Technology and Communications assets in the enterprise architecture.
PEOPLE MANAGEMENT	Identify the main characteristics of the culture of a company in order to adapt and improve strategies and tools for an appropriate organization and management
CREATIVITY	Identify business opportunities from key societal challenges for the medium / long term.
POPBL	Use a methodology to solve a complex problem (know, understand and apply) and collect it in a document.

3.2 The didactic method

The present didactic method helps to get a global overview of the entire process, starting from the initial idea to the solution of the problem. Through this process, the content that the student work on is meaningful and relevant for them, since they work on real world's situations and problems. Therefore, as well as turning knowledge acquired from the classroom into useful knowledge for solving the POPBL, they have to search for information in order to solve these real problems and generate their own deep knowledge so as to transfer to other areas.

In addition, the context through which the projects are developed allows the students to develop "three core competences": i) technical skills that will help students on their future technical daily duties; ii) methodological knowledge focused on project planning and development; and finally, iii) "soft skills" in order to improve their integration at work, team working with colleges and customers, effective communication, problem solving, creativity, etc.

Regarding the different stages of the POPBL, Figure shows the sequence of the phases for its conception.

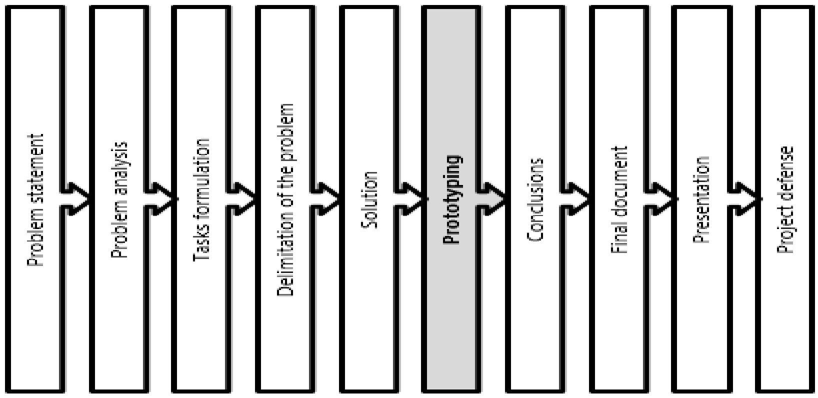

Figure 1 Activities done through the POPBL process, adapted from Val, Zubizarreta, and Justel (2006)

One of the key factors for the success of a POPBL approach is to connect it as much as possible to the real world, developing a scenario that simulate a real world situation. Concretely, regarding the Bachelor's Degree in Engineering in Industrial Organisations all POPBL are defined by teachers. Thus, in order to be the closest possible to the real word the third course of the Bachelor's Degree in Engineering in Industrial Organisations as established the prototyping as a core element of the POPBL. During the POPBL students might build a physical prototype so as to test assumptions on which the proposed solution has been built. In addition, the prototype works as a tool to integrate experiential learning (Nuldén & Scheepers, 1999) and move the industrial reality closer to the classroom.

It has to be highlighted that among the different types of prototypes (see Table), students has worked on developing a visual, proof and presentation prototype. They were not able to a pre-production prototype. In addition, all this prototyping is "lean orientated" in order to achieve cost-efficient and accurate enough prediction of the solution proposed.

Table 1 Types of Prototypes

Types of Prototypes	Description
Visual prototype	This type of prototype conveys the overall shape and size of the product but does not usually prove the function of the idea.
Proof of concept prototype	A prototype that demonstrates the main functionality of the idea. This type of prototype will probably make use of 'off the shelf' components and is unlikely to look like the final product.
Presentation prototype	This type of prototype combines the functionality of the product with the overall appearance.
Pre-Production prototype	This type of prototype builds on the work of a presentation prototype by fully considering mass production manufacturing methods and production.

3.3 The agents

Agents involved in the application of this new approach are both, teachers and students. Besides, it has to be highlighted that the role adopted by teachers has several aspects:

- First of all, each subjects' teachers develop their traditional role of educators transmitting the course contents through lectures. In these classes, students are provided with the basic theoretical knowledge of each discipline, to serve them as a basis for the project.
- In addition, these teachers are experts of these subjects and students can turn to them when they need technical support. The amount of time that each team of students can consume with each teacher-expert is limited to a predetermined amount at the beginning of the project. Project teams, if they wish to be treated, are required to request a meeting with the expert-teacher attaching an agenda of that meeting.
- Finally, teachers also take on the role of tutor. A tutor to each project team is assigned whose function is to guide students throughout the project, staying out of the technical difficulties. As mentioned above, these technical difficulties must be resolved with each subject-expert teacher.

Due to the change in the teachers' role, students must behave differently from the traditional way. On one hand, the lectures provide them with the theoretical basis needed to carry out the project will serve to develop their knowledge about it; and on the other hand, each team has a tutor whose main role is to provide students with the necessary tools. Finally, the technical difficulties that arise during the project are solved with the help of the expert-teacher.

3.4 The POPBL project

The objective of the projects undertaken under this framework is "to identify new business opportunities based on a specific problem"; concretely this POPBL seeks to developed an aerial system (a prototype) that allows recording images at a minimum height of 5 meters and accessing impossible places for several reasons (such as little space, private places, etc.) and to identify a new business opportunity based on the previous aerial system. The challenge is the established for all the teams, and each team has to work on a different solution.

The POPBL had three consecutive milestones and each milestone had its specific deliverables (see Table 2):

Table 2 Milestones and deliverables

Milestone	Deliverable
1st milestone	• The process followed and tools used for selecting the system that best meets the requirements. • The technical description of the aerial system to be developed; with drawings, calculations etc. • A detailed planning of the project. • A report of the organizational structure of the team based on Mintzberg's alternatives.
2nd milestone	• Presentation of the developed aerial system and the cost of the prototype. • Requirements of web development (Moqups and description of functional requirements). • The marketing plan.
3rd milestone	• Enterprise Architecture. • Plan for economic viability of the business model. • The web page to promote the final work. • Marketing Plan: Strategic decisions and action plan. • Poster reproducing the proposal and selling the work done. • A video reproducing the proposal developed as a summary. • A final report reflecting all the work done during the project. • A report on Belbin Team Roles.

For this specific POPBL, there were established 3 teams of 9 members, in order to simulate real projects (usually a high number of members participate and have to be managed in a real project) and work on project management. Previous to the beginning of the POPBL, students define by themselves the teams. Each of the teams developed a different aerial system in order to solve the previously established problematic. In addition, each team developed a "presentation prototype" and a possible business opportunity based on their solutions (see Figure 2).

Figure 2 Posters and Prototypes

3.5 The evaluation system

The main problem with group work is that, some students gain a lot of qualification but some of them gain nothing because they left everything to the others. Therefore, teachers should focus on the achievement of every student rather than every group. They should allocate the marks fairly and accordingly and they must avoid allocating the same mark to every student in a group because this situation can lead to the problem of free-riders (Mohamed, Mat Jubadi, & Wan Zaki, 2012).

Indeed, each teacher-expert measured the technical part of the final report and the individual project defence related to their subject. Therefore, the allocation marks for each subject were as follows:

- The technical part of the final report (30%)
- Individual project defence (70%)

Regarding the subject called POPLB, which measured the transversal skills acquired by the students, its allocation marks were as follows:

- Final report format (30%)
- The prototype (50%)
- The final presentation (20%)

In addition, students also have the mechanism to evaluate and give feedback about the POPBL. Once the POPBL is finished, students are surveyed and asked about the project. Concretely, the survey is based on 9 closed questions: the first 8 questions are measured using a 5-point Likert scale (from strongly disagree to strongly agree) and the last question indicating a number. In the following lines these items are listed:

- I think that the POPBL is an appropriate methodology in order to work on, understand and internalize technical skills.
- The POPBL methodology motivates me through the learning process, since this methodology makes sense of what I am studying.
- Through team-working (in comparison with individual-work) I learn communicating with people, learning from others, taking consensual decisions and sharing responsibilities.
- The project I have developed this semester has been interesting.
- The tutor has helped us through the project, promoting reflection of the problems that have arisen.
- The experts have helped us to resolve the previously prepared questions we made.
- Doing the presentation of the project has helped me to improve my communications skills.
- The projects defence has helped the whole team to know about all the different topics worked on and to assess the knowledge level of us.
- My personal dedication for working on the POPBL, outside of school hours, during the semester has been.

4 Conclusions

The intention of this paper has been to bring up a design model or method that includes prototyping within the POPBL methodology; since prototyping is one of the most important tools for experimenting and searching for solutions (Brown, 2009), as well as for testing assumptions on which their solution has been built.

Through the present POPBL implementation, students have experienced a great self-learning process. They not only learn about how to get the task done but they also learn about how to handle a group and being a leader. Concretely, through this approach students have been provided with mechanisms that allow them to acquire and develop both technical skills and transversal skills such as teamwork, leadership, communication and self-learning. In addition, the development of prototypes reveals student's practical ability and application of theories learned (Awang, 2007).

Results obtained in this case study shown that the prototyping within the POPBL is a promising technique to be introduced in other courses with a well organised planning. In addition, this type of POPBL could be applied within other technical or no-technical degrees, since prototyping allows to be closer to real situations; which is a necessity for any current degree. However, it is noted that further improvement needs to be considered in terms of a problem crafting and industrial collaboration.

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E-learning environment for Electronics in Physics Degree

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Abstract

This document presents a new global e-learning setting in the field of Electronics in the Degree in Physics that allows the integration of different itineraries as a function of the profile of the student. The implementation of this learning strategy enhances the learning autonomy of the students and introduces them to the methodologies and tools typically found in the field of Microelectronics from a professional point of view.

Keywords: active learning; collaborative work; e-learning; ICT; microelectromechanical systems (MEMS).

1 Introduction

Our higher education system is immersed into a novel teaching/learning paradigm in which specific and generic competencies are trained while it integrates itself in an information and knowledge society (Brandsford, Brown, & Cocking, 1999). To achieve this, it is essential to focus the teaching on the student and to choose the teaching methodology according to the learning strategy.

The shift to a training based on competencies requires that teachers and students adapt their conceptions and usual practices to achieve the new educational goals more effectively. To accomplish it, information and communication technologies (ICTs) have been proved to be an exceptional tool: they facilitate, promote and support student learning autonomy and at the same time they help teachers to guide, support and coordinate students (Kirkwood, & Price, 2005).

ICTs have a wide range of applications in the classroom (Olmo, Gomez, Molina, & Rivera, 2012; Zuniga, Pla, Garcia, & Dualde, 2012), but among them their application to perform student supervision tasks stands out, mainly due to the fact that now the student and the teacher do not need to coincide in space and time. Besides, ICTs allow the creation of discussion forums in which the teacher can analyze, rate and give feedback, and even keep record of every student's evolution. In general, the realizations of ICTs with the highest potential for education are those that allow an increase of the presence of the teacher in the students' learning process, providing them with relevant and rapid guidance.

The project described in this paper is implemented as part of the portfolio of a Degree in Physics. In particular, the students targeted are enrolled in courses taught at the Electronics Area: Digital Systems, Micro and Nano Systems, Physical Electronics, Physical Techniques I, II and III and Radiation Detection Systems from the Grade in Physics, and Signal Analog Processing, Microelectronic Design, Artificial Neural Networks and Applied Techniques in Physics from the Master in Physics and Physical Technologies. These courses have a close link to industrial and technological applications, thus facilitating a less theoretical approach to the materials than what is common in a Degree in Physics. It also has to be noted that this belongs to an overall mixed learning strategy, in which synchronous learning is put into practice as well.

In this project, a set of specific teaching resources making up a learning environment is created to promote blended learning. It allows performing different itineraries as a function of the profile of the student. The resources are hosted in a teaching e-platform and they constitute a comprehensive set of tools for the teaching/learning process and for its evaluation.

2 E- Learning environment

The proposed e-learning environment contains learning resources (notes, manuals, webinars, Matlab interactive animations and specific tools) and learning activities (Java animations, quizzes, simulations, wikis).

2.1 Learning resources

Applets. Students are provided with a library formed by a set of Matlab interactive applications (applets) that cover the main concepts studied in the courses of the Electronics Area. By the use of the applets, students complement the analytical treatment conventionally given to topics such as the fabrication and operation of electronic devices, which facilitates their understanding.

Webinars. A first webinar module is programmed that has a synchronous nature and is specialized. It consists of four 90 minute sessions dealing with the design and fabrication of microelectronic circuits in the shape of virtual classes. A second module, characterized by distributed and asynchronous learning, is aimed at students of the discipline and other degrees. A set of videos are projected to give students a realistic view of the industrial processes involved. In particular, the videos deal with: (1) design and simulation of a MEMS, (2) fabrication process, and (3) microelectronic systems in today's processes and instruments.

Simulation tools. Students have access to academic licenses of the Cadence design environment and to finite elements simulation tools. Also, they are asked to find and use some of the free simulation tools available in the Internet and compare them with the professional tools.

Tutorials and lectures. The e-learning platform hosts a set of tutorials that lead students into the most relevant aspects of the tools they use, providing them with working examples that serve as a reference. Fig. 1 shows some screen captures of these tutorials. Finally, a set of lectures, designed as a standard expositive session, is given to students to present the theoretical foundations of the topics studied in the course.

Figure 1: Screen captures of the tutorials in the e-learning platform.

2.2 Learning activities

The learning activities include the following:

Quizzes. A self-evaluation system consisting of a set of short questions or quizzes is integrated in the course so that students have an immediate feedback about their learning process that fosters their metacognitive capacities (Dochy, Segers, & Sluijsmans, 1999). These quizzes are designed for all the resources of the course: applets, virtual laboratory session, etc.

Applets. Students are asked to adapt the applets provided, changing the most significant parameters governing the phenomena under study and their dependencies. This improves their understanding of operation and fabrication of electronic devices by a visual description that complements the conventional analytic approach (Salinas, 2004), covering specific fields such as (1) manufacture of integrated circuits, (2) semiconductor physics, (3) semiconductor devices, and (4) micro and nano systems.

Virtual laboratory. With the help of the simulation tools presented to the students, a set of virtual laboratory sessions are scheduled in which students analyse the behaviour of these systems by means of simulation results. In this virtual laboratory, the students deal with the characterization of electronic elements and basic blocks (with Cadence) and the process of design of MEMs (with Elmer and Salome). Fig. 2 shows several screen captures of the MEMs design virtual laboratory.

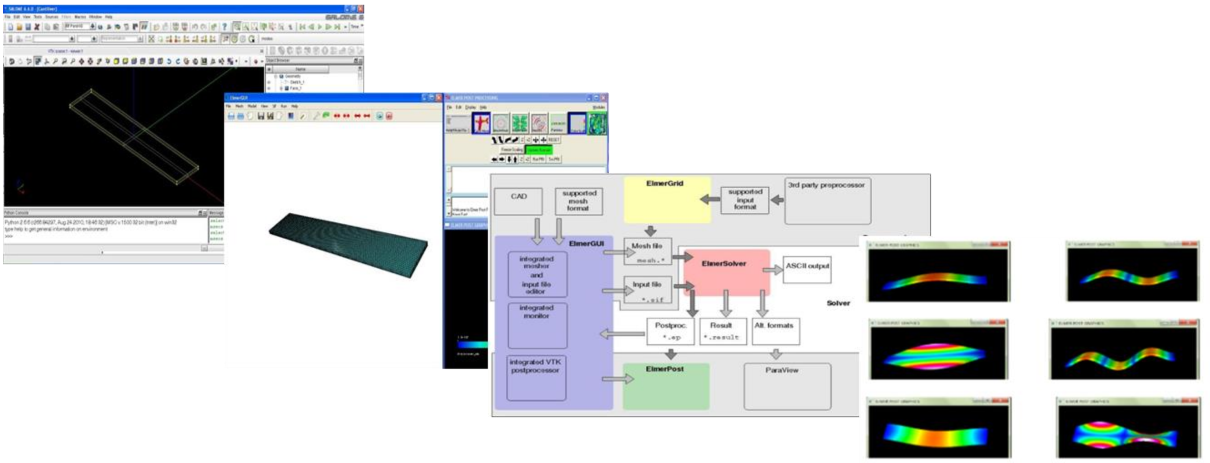


Figure 2: Screen captures of one specific virtual laboratory session.

3 Development

An introductory expositive session is set to explain the learning process and present the learning e-platform, which, along with the resources listed above, hosts detailed information about the different programmed activities and a schedule. Different screen-shots of the learning e-platform can be seen in Fig. 3. Even though sharing common activities, students of each course follow a different itinerary so that they can plan their own learning path. This is shown in Diagram 1. This virtual learning environment is led by the teacher and it offers learning complementary to that obtained in the classroom by the use of different strategies and tools to present the concepts. The different topics are presented by a combination of problem-based learning (PBL) (Perrenet, Bouhuijs, & Smits, 2000) and case study (Fry, Ketteridge, & Marshall, 2009) so that students solve the challenge (PBL or case) using the tools hosted in the e-learning platform as a complement to the traditional classes. In this way, students develop a portfolio covering all aspects relevant to the design and experimental characterization of microelectronic systems. Some of the generated results are presented in wiki format, since wikis promote active learning, improving and stimulating cooperation.

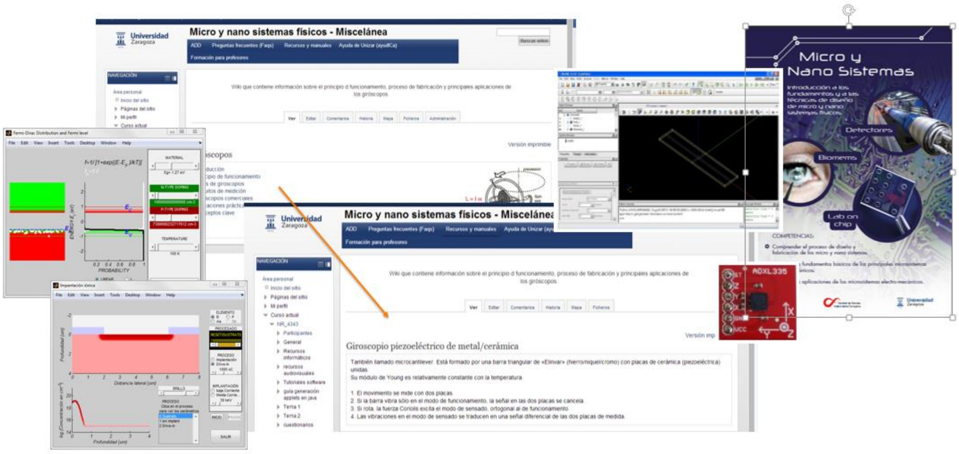
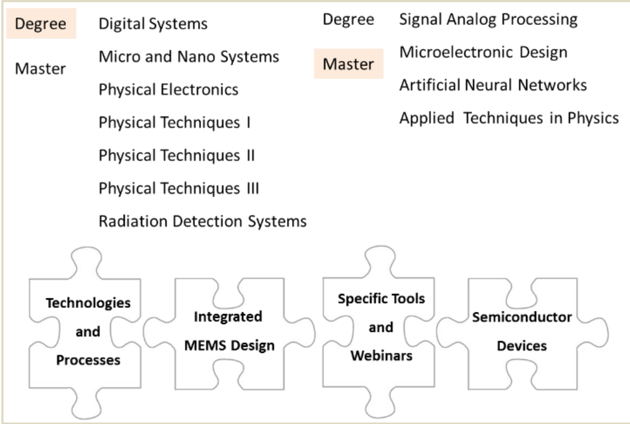
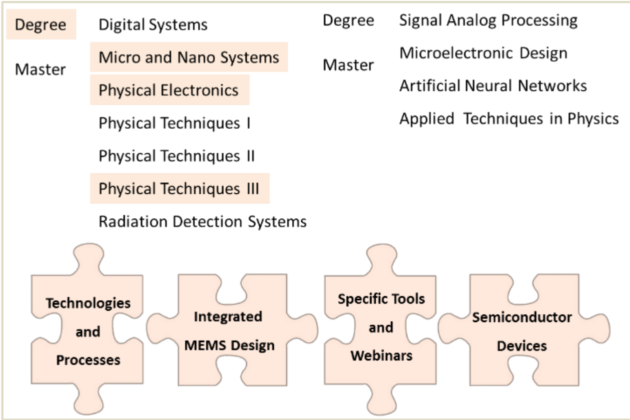


Figure 3: Screen captures of the e-learning platform.

The applets library includes topics that cover the main concepts studied in the courses offered by the Electronics Area. The specific realizations of the applets have been broken down into three main blocks with three sub-blocks: (1) fabrication of integrated circuits (ion implantation and diffusion, photolithography, and metallization and planarization), (2) semiconductor physics (drift velocity, dependency of carrier mobility with temperature, and Fermi-Dirac distribution and Fermi level), and (3) electronic devices (the diode, the MOS



(a)



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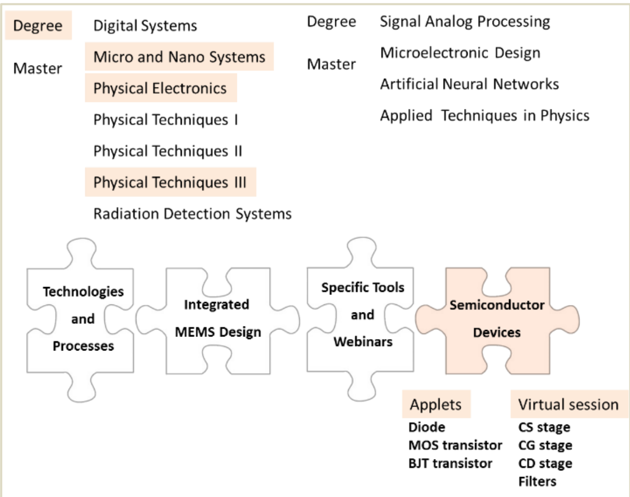
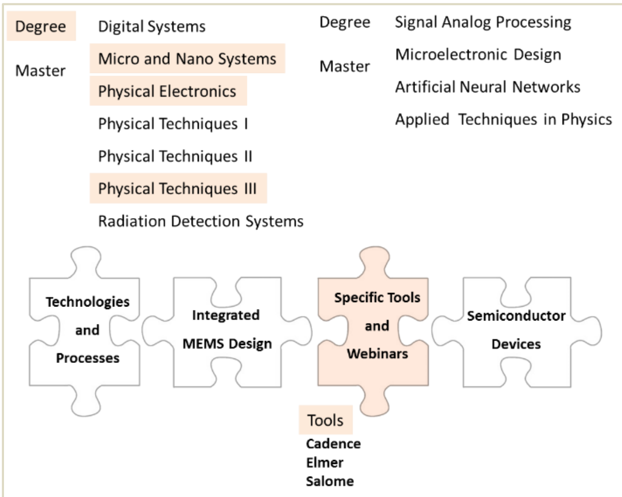


(c)



(d)

Diagram 1: (a) shows the general structure of the e-learning environment, with the list of courses belonging to the Degree in Physics and the Master in Physics and Physical Technologies (top), and the knowledge blocks. (b) shows an example of a possible itinerary by a student of the Degree in Physics enrolled in the highlighted courses: he/she has access to activities belonging to all knowledge blocks. (c) and (d) show the specific resources that the student has access to particularized for two of these blocks.

transistor, and the BJT transistor). PBL method is used for the first and second blocks and case study for the third one.

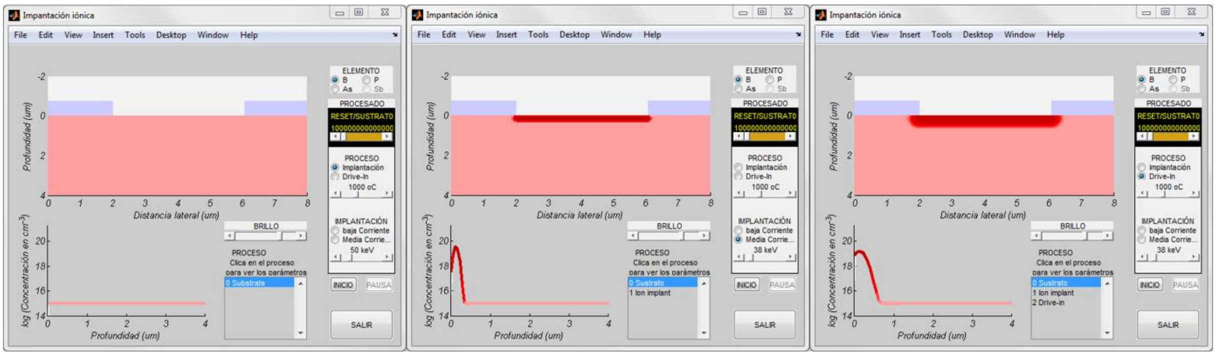
The virtual laboratory sessions are aimed to the design and characterization of electrical and mechanical systems, as the basis of smart sensors, using professional tools so that they can develop their skills in an environment as realistic as possible. The study of behaviour of basic amplifier stages, filters or the design of cantilevers are some of the activities proposed in this block.

The following paragraphs illustrate some of the activities proposed to the students within the different itineraries. For the purpose of contextualization, an example is taken from each block to describe the activities carried out by each group and the results obtained by them.

Fabrication of IC.

This first activity deals with the processes involved in the fabrication of integrated circuits. As an example, the activities related to the sub-block of ion implantation are presented.

Ion implantation is a process by which ions are accelerated and impacted into a solid. In the fabrication of integrated circuits, it is used to dope silicon to modify its conductivity in the vicinity of the region impacted, since depending on the ions used for implantation the resulting region can be of N-type (implanting phosphorous or arsenic) or P-type (implanting boron). The applet allows changing the main characteristics of the implantation process such as the type of ion implanted, the energy before impact or background doping of the substrate. Fig. 4 shows the initial configuration of the applet that simulates the process of ion implantation.



(a) (b) (c)

Figure 4: (a) Matlab applet to simulate ion implantation. Results obtained for the ion implantation process: impurity concentration profile (b) after implantation and (c) after annealing and drive-in.

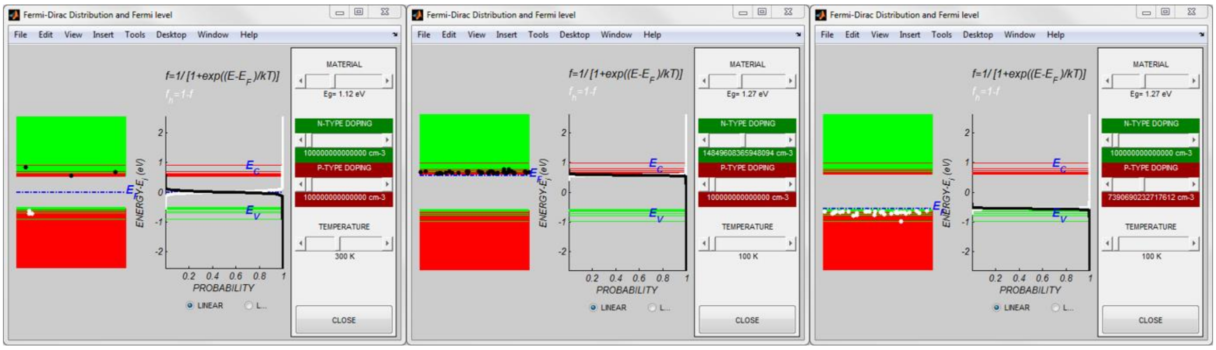
Students are asked to solve typical problems relating to implantation using the applet as a complement, allowing them to achieve a deeper comprehension of the equations that state then analytically, which constitutes a great source of help to enhance their learning process.

Semiconductor physics.

This activity analyses the models typically used to describe the behaviour of carriers (electrons or holes) in semiconductors: how they move in an electric field (carrier drift), the dependence of their mobility with temperature, and their distribution in the energy band structure. The activities carried out by the students are presented using the Fermi-Dirac distribution and the Fermi level as example.

Electrons belong to a group of particles called fermions. Fermions satisfy the Pauli Exclusion Principle, which states that no two identical fermions may occupy the same quantum state at the same time. Mathematically, a system formed by many non-interacting fermions in thermodynamic equilibrium is represented by the Fermi-Dirac distribution. From the Fermi-Dirac distribution it can be shown that at the absolute zero (T = 0) all single particle states whose energy is lower than a certain value μ are occupied whereas all single particle states whose energy is greater than μ are empty. μ is called the Fermi level.

For this and the other sub-blocks, the applets allow changing critical properties of the semiconductor such as its energy gap or the concentration of impurities and other such as the temperature. Using them, students can visualize the physical meaning of the mathematical expressions used to describe semiconductor physics, which proves crucial for a correct understanding of the physics behind electronic devices. Fig. 5 shows the applet that simulates the Fermi-Dirac distribution.



(a) (b) (c)

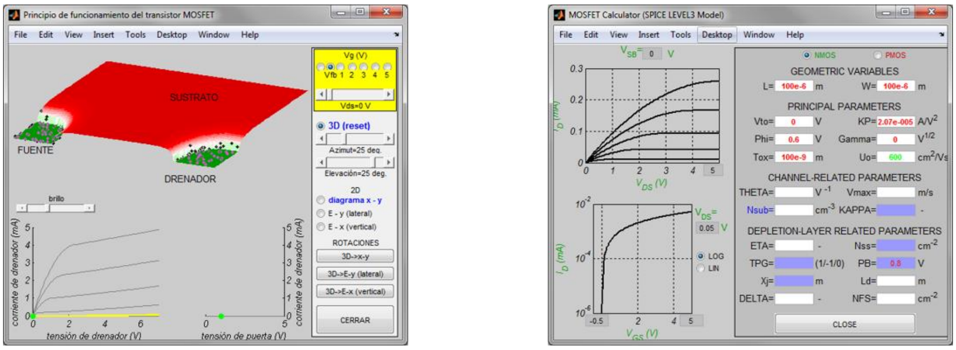
Figure 5: (a) Matlab applet to simulate carrier concentration following the Fermi-Dirac distribution. Carrier distribution and Fermi level for (b) an n-type and (c) p-type doped extrinsic semiconductor.

Electronic devices.

This activity uses case study, which is typically reserved for postgraduate training although it has a promising potential for undergraduate education since it provides a different perspective to link theoretical concepts to actual experimental methodologies and results.

In this activity, students are provided with real experimental data of an electronic device to interpret the results using the theoretical descriptions given in the classroom and the results obtained with the applet. Continuing the approach followed in the paper thus far, the activities carried out by students are shown particularized for a concrete electronic device: the MOS transistor.

Fig. 6 (a) shows the applet used to visualize the operation of an MOS transistor. In it, a 3D representation of the distribution and movement of carriers is shown along with a plot of its DC drain current as a function of its drain-to-source and gate-to-source voltages. For its part, Fig. 6 (b) shows the applet used to simulate the operation of an MOS transistor with level-3 SPICE, a simple simulation model long replaced by newer models (for instance, today modern simulators use level-54 SPICE).



(a) (b)

Figure 6: (a) Matlab applet to visualize in three dimensions the movement and DC characteristics of carriers in a MOS transistor and (b) MOS transistor operation according to level-3 SPICE model.

Students can change the main parameters of the MOS transistor and modify its operation conditions (voltages and currents) to compare the simulated results with those obtained by analytical expressions. Also, they are provided with experimental data of the operation of MOS transistors so that they can compare them with the simulated ones, realizing the need to develop more and more complex numerical models to bring the predicted behaviour of electronic devices closer to reality.

With this activity, the students can evaluate the correctness of analytical solutions obtained using approximations and identify possible improvements, a usual procedure to create new models in science.

MEMS.

This block is also approached using the case study strategy to introduce the students to the use of professional tools for the design and characterization of a MEMS. This includes materials such as Matlab applets to be adapted to the MEMS under study; specific design and fabrication software (an open source computational tool for multi-physics problems which uses the Finite Element Method), and a free piece of software that provides a generic platform for pre- and post-processing for numerical simulations, making the integration of new components on heterogeneous systems for numerical computation easier. One of the activities proposed here is the design of a cantilever, which is the basic element of the operation of an accelerometer, so that they work with the CAD-CAE layout tools for MEMS and electronics design that a professional would use. The accelerometer is chosen because it represents a natural bridge between MEMS/NEMS and the curriculum of a degree in Physics; in particular, its experimental characterization requires the use of concepts of kinematics with which students of a degree in Physics are familiar.

4 Evaluation

The evaluation is done by several actions distributed along the course to assess the progress of the students in understanding the concepts, which serve them as milestones for a correct time planning of their work. The set of registers generated in the learning itinerary proposed to each student constitutes the portfolio, which is also used as an evaluation instrument. Examples of these activities are: resolution of general questionnaires, presentation of concrete and realistic applications, or elaboration of animations using Matlab applets.

A self-evaluation method is integrated in the different activities. It consists of a set of quizzes that allows students to have immediate feedback about their learning process, thus fostering their metacognitive capabilities and integrating the evaluation in a natural way as just another activity of the learning process.

Finally, students can develop a wiki page containing information on the studied systems, their operating principles, fabrication process and related relevant information. The main goal of the activity is to enhance the students' learning experience and foster teamwork, cooperation and multidirectional asynchronous learning. The wiki is hosted in the e-learning platform using the MediaWiki and, since the system registers the identity of the person editing the wiki, the individual work of each student can be continuously supervised.

All this is intended to produce three learning outcomes associated with the contents of the itinerary in Electronics. In particular, what is sought is that the student:

- Is able to describe the process of manufacturing of a microdevice.
- Is able to describe the semiconductor physics behind the behaviour of an electronic device.
- Is able to handle the different electronics devices in a circuit.

The application of the system proposed in this work improves the teaching results in the following aspects:

- It enhances the understanding of the physical phenomena behind the operation of the semiconductor devices and micro y nano systems achieved by presenting a visual description that complements the traditional analytic approach.
- It encourages the use of specific applets to support the study of the different topics and to made students acquire a deeper understanding of these processes.
- The use of specific informatics tools for design and simulation allows getting familiar with the professional resources used for the design and characterization of micro y nano systems while developing a collaborative work in a realistic environment.
- It fosters the students' learning autonomy and the active and participative teaching.
- It promotes the conditions leading to the establishment of peer learning.

5 Conclusion

This work shows a global e-learning environment creation that comprises the introduction of varied and specific teaching resources to improve the teaching/learning process in transverse topics of courses from the Area of Electronics in the Degree in Physics, allowing the integration of different itineraries as a function of the profile of the student.

This learning strategy enhances the learning autonomy of the students, which is of critical importance for the development of their future careers, in which they will have to engage in continuous and autonomous learning. Also, due to how the experience is structured, it makes students face a wide range of the typical issues that arise during the planning and implementation of a medium-term project.

The implementation of this learning strategy also introduces the students of the Degree in Physics, which has a very strong theoretical load, to the methodologies and tools typically found in the field of Microelectronic. This is of particular importance from a professional point of view because Microtechnology is a natural field of employment for graduates in Physics where they will typically take part in teams along with professionals with an engineering background.

To finish, it is important to mention that this is a novel experience in the Degree in Physics and can be exported to other knowledge areas.

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RPAS from Cradle to Flight: A Project Based Learning Experience

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Abstract

Aerospace engineers face multidisciplinary problems. These require integrating technical knowledge from different subjects, balancing it with skills and competences. Third-year Aerospace Engineering students from the Universidad Europea de Madrid (UEM) have been asked to develop a project as if they were working for a company. They present their work here. It was done following the Project Based Learning (PBL) methodology implemented at the Project-Based Engineering School (PBES) of the UEM. The project was aimed to design, build and test a Remotely Piloted Aircraft System (RPAS) by involving four different subjects. A team of 10 students was involved in the project. It was not just an educational project but a real engineering project. Therefore, it has allowed the students to know, understand and practice the process through which a real product is made. The project has led the students to perform in a professional environment, getting them closer to their future jobs and thus motivating them. They have achieved deeper learning and developed key skills such as teamwork, decision-taking, planning and time management. It has also fostered entrepreneurial spirit by transforming the project into the seed of a Start-up company. It has been presented to the first "HUB Emprende" call of the Universidad Europea and it has been distinguished as one of the ten winners, being awarded with an incubation program that helped the students develop their business project.

Keywords: Project-Based Learning (PBL); aerospace engineering; Remote Piloted Aircraft System (RPAS); key skills.

1 Introduction

The aerospace engineering design process is complex and iterative, and it is normally not learnt when using traditional teaching at university. Projects and problems that must be solved by aerospace engineers usually require cooperative strategies. Aerospace engineers must be able to work following an iterative process where individuals and teams work in parallel. The problems they face are multidisciplinary and require integrating technical knowledge from different subjects. Besides, this problem solving process also requires fluent communication between the team members as well as good cooperation between them, balancing technical knowledge with skills and competences.

These are the main reasons why third-year students from the Aerospace Engineering degree have been asked to develop a project as if they were working for a company, using the Project Based Learning (PBL) methodology. This project involved 4 subjects: *Mechanical & Graphic Design*, *Fluid Mechanics II, Aeronautical Structures & Vibrations,* and *Aerodynamics*. Its scope included the design, structural and aerodynamic analyses, manufacturing, assembly, testing, entry into service and operation of a Remotely Piloted Aircraft System (RPAS).

This paper presents the project development from the point of view of one of the students involved in it. This way, a closer view is provided of what actually has been occurring during the development of the project.

1.1 The RPAS project within the Project-Based Engineering School (PBES)

Project Based Learning (PBL) is a methodology based on the concept of *learning by doing* (Blumenfeld, et al., 1991; Thomas, 2000). Using a project as the context, this approach seeks deeper learning among the students and development of transversal competences which are highly valued in the professional world (Fallows & Steven, 2000). Following this methodology, the Polytechnic School of the Universidad Europea de Madrid (UEM) established its own Project-Based Engineering School (PBES) in the 2012-13 academic year having the following global objectives (Gaya López, et al., 2014; Terrón López, García García, Gaya López, Velasco Quintana, & Escribano Otero, 2015):

1. Increase the motivation and pride of belonging of students and teachers.

2. Achieve a deeper learning in the students.
3. Develop key skills.
4. Bring the lecture room closer to the profession (and vice versa).
5. Focus on social, economic and environmental sustainability.
6. Encourage entrepreneurship, technological innovation and internationality.

Aerospace Engineering is one of the degrees involved in this PBES. Teachers are asked to propose projects that involve several subjects each year. Learning through projects will give students a hint of what they will find in their future professional careers.

The academic year structure at the UEM is divided into three quarters. Each quarter, students are enrolled into usually 3 or 4 subjects of 6 ECTS (European Credit Transfer System) each. During the 2014-2015 academic year, the project for third-year Aerospace Engineering students was to develop a Remotely Piloted Aircraft System ("RPAS project") in order to learn the technical competences required to develop such vehicle while examining the currently widespread interest in the development of civil applications for this technology (Hsiao, et al., 2005). RPAS, colloquially known as *drones*, are aerial vehicles that fly without an on-board pilot, as well as the systems that support them to do so (Boucher, 2014). Perhaps the most established and visible applications of RPAS are for military purposes, but many applications have been identified for domestic uses and therefore the gradual integration of civil RPAS into normal airspace is a current reality. This is one of the main reasons for the project: to motivate the students by doing work which is closely linked to what is happening nowadays regarding their field of study.

The students involved in this project were those enrolled in at least one of the following subjects of the 3rd year of Aerospace Engineering: *Mechanical & Graphic Design*, 1st quarter (September-December, 2014); *Fluid Mechanics II*, 1st quarter (September-December, 2014); *Aeronautical Structures & Vibrations*, 2nd quarter (January-March,2015); *Aerodynamics*, 3rd quarter (April-June, 2015). They had to design and build the RPAS in a team involving at least 10 students, operating in a collaborative environment (working with others efficiently and sharing responsibilities). The project was divided into different phases based on those of a real aerospace engineering project cycle (Kamp, 2011): explore the options, conceptual design, detail design, test and simulate, and verify and validate. These phases were adapted to the subjects involved in each quarter. The project should be finished by the end of June 2015.

1.2 Scope of the RPAS Project

The scope of the project focused on the following tasks or phases in order to reach the final product: Design of the RPAS; Structural and aerodynamic analyses; Manufacturing and assembly; Testing; Entry into service and operation of the RPAS. Performing all these tasks should help the students know the process through which a real engineering product is made, understand how it works and train through its application, as well as help them develop some key skills required in their future jobs. The final goal is to provide an overall view, during the university course, of the entire Vehicle Life-Cycle through the integration and interrelation of the subjects involved in the project.

2 RPAS project development and phases

A team of ten students from the four main subjects detailed in section 1, mentored by their teachers, was in charge of transforming the idea presented in this paper into a final operative RPAS. Therefore, their first task was to organize the team (establishing rules, team roles and responsibilities). The project was structured in a similar way to a real engineering project. The teacher defined the 6 main departments in which the project should be divided and named a student as the "Program Manager". This student had to decide who the "Chief Engineer" would be. The "Chief Engineer" then had to decide the students in charge of each department (i.e. "Chief of Design", "Chief of Systems", "Chief of Stress", "Chief of Aerodynamics", "Responsible of Payload" and "Communication Officer"). These students were responsible for their respective departments but everyone could work in a certain task of a different department if their help was required. The rest of the students would work for the different departments depending on the tasks being performed at each time. The project structure is graphically shown in the following figure:

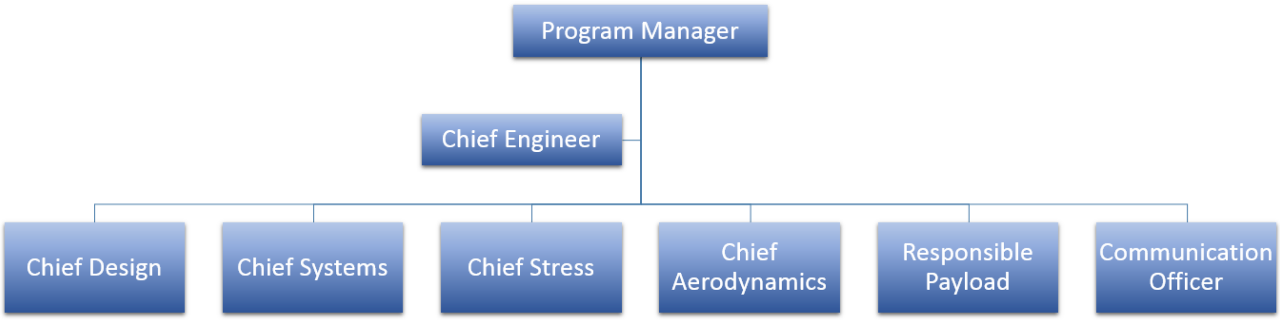

Figure 1: Initial project structure (assignment of roles)

However, during the development of the project, the students decided that this project structure was not very efficient due to the tasks that had to be performed (some departments had too many tasks and others had just a few). Therefore, a new project structure, with two main branches, was proposed and applied: "Design and manufacturing" and "Product development and marketing". Each one of these branches was then divided into small, task centred teams. Most of the students were involved in more than one of these "sub-teams". Besides, the different work packages that had to be delivered (with their respective deadlines) where defined according to the five project phases.

2.1 Phase 1: Design of the RPAS

First, the students had to define the mission and requirements of the RPAS. Therefore, they had to explore the different options following the aerospace engineering project cycle (Kamp, 2011). Then, they had to develop the optimum design to meet those requirements. The design phase took place during the first quarter and beginning of the second. It was divided into four sub-phases, defined as exploring the options, maturity A (involving the conceptual design of the RPAS); maturity B (consisted of the preliminary and detail designs); and maturity C (final design including the improvements defined at the end of maturity B). In this phase the students had to be aware of not only technical aspects but also other factors such as safety, available resources, and regulations since these are as important as the former ones. The operations optimization was sought during this phase. Special consideration was given to safety issues with regard to the final user of the RPAS. The main subjects involved in this phase were *"Mechanical and Graphic Design"* and *"Aeronautical Structures & Vibrations"*. During the former, the students had to present the progress of the project at certain key points of the design process. Two important presentations were prepared during this subject, after finishing maturities A and B. The latter subject was involved indirectly.

2.1.1 Exploring the options

The defined mission for the RPAS was infrastructures' inspection and surveillance. The device was intended to inspect and scan buildings in order to examine if there is any structural damage or loss of energetic efficiency. In addition, it could also be used for surveillance and event image streaming. Considering this, the first activity to be done by the students was a literature study to understand RPAS and their different configurations. By doing this the students developed their *autonomous learning skills*. However, this task was mainly done by the Program Manager and the Chief Engineer, who first did some research and then explained their findings to the rest of the team.

This was the first time students were aware of the importance of good planning. Therefore, they established some milestones in their long term plan and they scheduled meetings where they had to do checklists for each week's work. Meetings were initially done weekly, but then (during maturities A and B) the students decided to have meetings every three weeks due to the amount of workload they had. Meetings were usually defined to be right after the "Mechanical & Graphic Design" class to ensure that the students would be able to attend. This process involved developing skills such as teamwork, planning and interpersonal communication, together with teaching them to develop responsibilities.

2.1.2 Maturity A

After analysing different possibilities, such as fixed-wing versus rotatory-wing designs, the students decided to design and build a medium-sized quadcopter in X configuration. This configuration was chosen instead of a fixed-wing design in order to enable the RPAS to stay flying steadily at a single position. Then the team had to choose between the different types of multi-copters (see table 1). It was done taking into account project sustainability, balancing between complexity, payload capacity and cost of the possible designs. Bicopters and tricopters were rejected due to the low payload they could carry and octocopters due to their high complexity and cost. The hexacopter was explored because of redundancy and due to its ability to carry more payload. However, finally the quadcopter option was selected for simplicity as well as lower cost.

Table 1: Multi-copter comparison table *(The UAV Guide, 2014)*

Multicopter UAV Type	Complexity	Redundancy	Payload Capability	Cost
Bicopter	High	None	Lowest	Low
Tricopter	Medium	None	Low	Low
Quadcopter	Low	None	Medium	Medium
Hexacopter	Medium	Low	High	High
Octocopter	High	High	Highest	Highest

By the end of October 2014, the team did an oral presentation including the specification of the RPAS' mission and the conceptual design, the defined project structure (i.e. distribution of the different tasks) and the identification of the systems required. As teachers wanted to accommodate students' learning to their findings, they assessed them in a formative way (without grade), providing some feedback about the project. They suggested some technical aspects to improve but most were about how the project was presented.

2.1.3 Maturity B

During this phase, the design of each one of the components of the RPAS 3D-model was done in the "Mechanical and Graphic Design" subject using CATIA (Computer Aided Three-dimensional Interactive Application). It is worth noting that as it was a real project, the students had to analyse the resources they have access to. So they could not just conceive incredibly outstanding ideas; instead the product had to be realistic and feasible ("closeness to the profession" competence). A final presentation was done at the end of the subject including the detail design of the RPAS, the selection of the systems and the estimated budget of the project. They also specified the improvements that would be done to the design during maturity C. This delivery (together with the assessment of the progress of the project throughout the entire course) was a 40% of the final grade of the "Mechanical & Graphic Design" subject.

Even though the subject of "Aeronautical Structures & Vibrations" is taught in the 2nd quarter, it was also involved in this phase because the concepts from this subject were necessary to be able to complete the RPAS design. Therefore, the students needed to have tutoring sessions in order to understand these new concepts, required to progress with the project. In particular, this subject helped with the sizing of the structural components and with the number and location of bolts and fittings to join components together.

Besides, during maturity B, the students found the opportunity of presenting the project to an entrepreneurship contest: the first "HUB Emprende" call (HUB Emprende, 2014).

2.1.4 Maturity C

In this sub-phase, the suggested improvements from maturity B were applied to the design. Maturity C indicated the end of the design phase. It was a very interesting moment for the students since they had come up with a final design and they were able to see the first results of their work (figure 2).

Figure 1: 3D model of RPAS final design

2.2 Phase 2: Structural and aerodynamic analyses

Parallel to the design phase, the structural and aerodynamic characteristics of the vehicle had to be analysed in order to demonstrate that the design of the RPAS would be both structurally robust and aerodynamically efficient so that it can be able to fly. The main subjects involved in this phase were *"Fluid Mechanics II"* (together with concepts from *"Aerodynamics"* in some aspects) and *"Aeronautical Structures & Vibrations"*. As it happened during the design phase, the former was involved directly and the latter, indirectly.

During the subject of "Fluid Mechanics II" the preliminary aerodynamic analysis of the RPAS was performed, using both theoretical concepts and a Computational Fluid Dynamics (CFD) software. This analysis had to be presented both orally and written. Three different presentations were performed in class, in October, November and December 2014 respectively, and a final report had to be submitted by the end of December 2014, having a weight of a 30% in the final grade. The first presentation included the stage of the project at that date, in order to show the main features of the project which started in the subject of "Mechanical and Graphic Design". The second presentation explained the general progress of the project and a conceptual analysis of the aerodynamics of the RPAS, including a comparison with existing designs. The third and last presentation showed the progress of the project and the preliminary aerodynamic analysis using CFD software. The final report contained all the different analyses, both conceptual and CFD, which were performed throughout the subject. The results and conclusions included in this report were not only focused on the technical data extracted from the analysis. They also explained the learning process attained through the different errors that appeared while performing the CFD analysis until the final solution was reached.

The subject of "Aerodynamics" was indirectly linked to this analysis too and some concepts were also explained in tutoring sessions with the "Aerodynamics" teacher. Besides, the "Aeronautical Structures & Vibrations" subject was again involved indirectly since a basic study of the resistance of the main structural components of the RPAS had to be done. A structural analysis report was done mainly due to necessity rather than as a specific task for a certain subject.

2.3 Phase 3 (manufacturing and assembly), phase 4 (testing) and phase 5 (entry into service and operation of the RPAS)

Once the final design had been defined, the components of the RPAS would have to be first manufactured and/or bought, and then assembled so as to obtain a physical prototype of the designed vehicle. However the project has been stopped for external reasons and this phase won't be completed for this project. This issue generated two different reactions on the students. Some students have become demotivated and have lost the interest in continuing with the project. However, others enjoyed so much the idea of the project that they are looking for alternative ways to build a prototype of the RPAS (outside the subjects but always with the support of the University). Two possible options are to build it with the help of "HUB Emprende" and/or to take advantage of the currently emerging "Aerospace Club" inside the UEM.

Once the RPAS is built, flight tests would have to be performed in order to demonstrate that the RPAS works as expected.

After completing all the previous phases, the RPAS would be ready to start operating for the defined mission. The initial idea was to use the RPAS to record the UEM graduation ceremony. Unfortunately, this wouldn't be possible since the Spanish regulation around RPAS has significantly changed in the past months and currently it is not permitted to fly these devices over crowded places.

3 The students' experience: developing transversal skills

This was not just an educational project but a real engineering project. On top of the importance of delivering a product by entry into service, it allowed deep knowledge of the process through which the product is made, facing the short and midterm challenges of the decision-making process. Likewise, it has stressed the importance of not so technical aspects such as procedures definition, the strict adherence to the requirements and the need for documentation of the entire process. Therefore, this project has led the students to perform in a professional environment and thus has motivated them. As previously mentioned, the project included a ten students' team. Other projects developed in previous academic years and subjects involved just up to four students. Therefore, students had to learn to coordinate larger groups of people, which made more problems and conflicts to arise. Together with *teamwork*, the students have developed several other transversal competences:

- *Ability to apply knowledge to practice*: the students had to use the knowledge they had from previous and current subjects in order to design the RPAS. On the other hand, as the project was a real one, they developed *closeness to the profession*.
- *Autonomous learning*: the students had to learn by their own several concepts that are not specifically taught during the degree. In addition, previous "forgotten" or "not completely understood" concepts had to be re-studied in order to understand certain issues of the RPAS.
- *Decision-taking*: as a real project, many decisions had to be taken during the design phase (such as the fact of selecting a quadcopter instead of any other type of RPAS).
- *Information management*: they searched about different RPAS designs and how they work, as well as for information related to the selection and characteristics of the components to be bought, such as the electronics and engines (during maturity B of the design phase).
- *Initiative and entrepreneurial spirit*: due to the good expected results the project has motivated the students to take it further presenting it to an entrepreneur university contest (HUB Emprende, 2014).
- *Innovation and creativity*: the innovation component of the RPAS design is of key importance in this project and the students had to focus on these aspects mainly during the design phase.
- *Interpersonal relationships skills*: developed in the same way as teamwork, through the constant communication and relations between team members.
- *Oral and written communication*: oral communication was developed through several presentations that had to be done along the design process; students had to document every modification made and deliver technical reports for the aerodynamic and structural analyses.
- *Planning and time management*: the need to coordinate the team members with every modification that has been made during the project helped students to improve this skill. Each team member had a different role and responsibility in order to diversify and better distribute all the necessary tasks.
- *Problem solving*: problems appeared and students had to find the optimum solution in each case.
- *Responsibility*: since the project requires performing a lot of tasks in a challenging time, responsibility was a key skill necessary in order to meet the different deadlines.

However, several drawbacks have also been present. On the one hand, the assignment of roles and distribution of the workload have in fact distributed the knowledge and thus not every member has learned the same, neither with the same deepness. On the other hand, since the distribution of this workload depended on the roles assigned, this has also caused some disagreements and frictions within the group members. In addition, although it was the same project, it was carried out in a different way in each subject, leading sometimes to students' confusion and more amount of workload.

4 Results and students' reflections

Students feel to have increased their motivation in their studies. As a matter of fact, even though they have just completed the first two phases (design and analyses), due to the motivation generated during the project development they are looking for alternative ways to build the RPAS elsewhere (still with the support of the University). The project has allowed the students to know, understand and practice the process through which a real engineering product is made. During the different phases of the project, the students have acquired deeper learning (integrating the knowledge from several subjects) and have developed certain specific competences mainly with respect to the design of the vehicle, while leading them to perform in a professional environment, getting them closer to their future jobs and motivating them.

Apart from the technical know-how, students have developed several transversal competences, from which teamwork, decision-taking, and planning and time management can be highlighted. As they had to manage a real project on their own, they had to plan their schedule and, in order to drive it in an efficient way, they needed to divide the work into different tasks to be done by different team members. They had to keep flexible in order to make the necessary changes throughout the project. Interpersonal communication (between students and with teachers) was also a key. Decision-making by multiple individuals (as a team) was relevant too. They had to share data, experience and opinions. The process may have been longer this way but decisions were more consistent, leading to better ones (compromise and consensus). Apart from this, they have also developed oral and written communication and responsibility.

They have worked with a project really close to the engineer profession. The process has shown the problems and challenges that appear in a professional environment, and it has helped them analyse possible solutions to those problems (such as re-defining the project structure to better suit the requirements of the project). Collaboration between the team members in order to reach the final goal was also necessary. During the decision making process some questions had arisen such as "how can I change this proposal so that it works for you too?", being similar to what a worker does in real projects, developing the ability to adapt to different situations.

They have focused their project on social, economic and environmental sustainability taking into account the civil applications and the safety requirements of the RPAS (social), the access to the available resources for it (economic) and the final design as a non-polluting and resource-optimized (environmental).

They have fostered an entrepreneurial spirit by transforming the project into the seed of a Start-up company, as well as technological innovation while developing a high-tech device. Converting the project into the seed of a Start-Up company has been explored, analysed and approved. This has shown how the PBL approach can substantially develop initiative and entrepreneurial spirit in the students when they enjoy and believe in what they are doing. The project has been presented to the first "HUB Emprende" (2014) call of the Universidad Europea and it has been distinguished as one of the ten winners (Universidad Europea, 2014). "HUB Emprende" is an ideas' incubator where entrepreneurship is supported. It is a business incubator open to the participation of students and alumni, as well as external projects of all sorts of sectors and disciplines. As one of the winners' project, the team has participated in a complete incubation program during 5 months (December-April). This program consisted in giving mentoring and specialized training to the students for free. Thus, they had the opportunity to receive counsel, advice and supervision to convert their business idea into a successful business project.

The incubation program comprised a training plan in which experts guided them in the key areas of the process: conception, maturing, contrast and definition of the idea; business plan, value proposition, innovation plan, legal support, communication plan, start-up pragmatic training and investment plan. By the end of these 5 months, on the 23rd April 2015, the team presented their project in a final "DemoDay" to the entrepreneurial and investing community (Hub Emprende Universidad Europea, 2015).

During the incubation program at the "HUB Emprende", the mission of the project has been modified in order to better meet both the demands of the current market and the requirements of the recent legislation that has emerged regarding RPAS. The business idea that has been developed there is to provide a service to the agricultural world by helping farmers optimize their resources. This would be done by using the RPAS to obtain critical information about the plantations. The fact of developing this project simultaneously at the University and at the "HUB Emprende" has in fact shown the students the importance of being able to adapt to different situations and has helped them develop even more their decision-taking skills.

5 Conclusions

The project has allowed the students to know, understand and practice the process through which a real engineering product is made, working in a professional environment and motivating them. However, drawbacks have also been present. The distribution of the acquired knowledge and the differences in the amount of workload for each student, both due to the assignment of different roles to each team member, has been seen as a problem. However, although several difficulties have emerged during the development of the project, it can be seen as a success. Some suggestions for improvement could be considered.

There should be a better coordination and communication between the different subjects involved in the project. Teachers should clearly identify which tasks would be performed in each subject and how to combine them with the others.

The project should be better organised with the subjects (in a chronological sense) so that students can apply the knowledge from each subject when required instead of having to grasp some concepts from future subjects beforehand, clarifying the real objective of the project from the beginning.

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Evaluating the Flipped Classroom Approach using Learning Analytics

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Abstract

The Flipped Classrooms is a learning approach that has the potential to provide quality engineering education. However, there is a lack of evidence demonstrating its efficacy as a quality teaching practice. In this paper we quantify the effects that the flipped classroom approach had on the performance of students on their course assessment tasks.

The flipped classroom approach was introduced for the first time to students in a second year Engineering Fluid Mechanics course to try to improve student motivation and engagement, and to try to improve cognition and understanding of the course material. Students worked through narrated, online eLectures prior to attending face-to-face workshop sessions. It was hypothesised that the more time students spent working through the weekly eLecture material, the better their results would be for the course assessment items. Learning analytics was used to investigate this hypothesis. Student viewing data was collected and analysed to determine whether there was a correlation between the total amount of time students spent on the weekly eLectures and their results for three of the summative course assessment tasks.

The study found a poor correlation with the time students spent on eLectures and the correctness of their answers to the weekly quiz questions and to their exam marks. While student feedback on the flipped classroom method was overwhelmingly positive and clearly demonstrated that students enjoyed and embraced the new teaching and learning approach, this did not appear to translate into significant improvements in student cognition or deeper learning.

Although the results of this initial study are generally inconclusive, and do not clearly either confirm or refute whether the flipped classroom approach was any more successful than traditional teaching approaches, the study has clearly demonstrated the intrinsic value of learning analytics as a tool to monitor student learning.

Keywords: Flipped classroom; learning analytics; classroom response systems; Mediasite.

1 Introduction

There has been much attention given recently to Flipped Classrooms and it seems that higher education institutions everywhere are embracing this learning approach as the next solution to providing quality engineering education. However, there appears to be a distinct lack of evidence demonstrating that the Flipped Learning approach is any better than other quality teaching practices.

In this study, the flipped classroom approach was implemented for the first time into a second year engineering Fluid Mechanics course to try to improve student motivation and engagement, and to improve cognition and understanding of the course material. There were 66 students in the Fluid Mechanics class.

In order to promote more student engagement, and to improve student participation and interaction, a new type of classroom response system (CRS) called Learning Catalytics (LC - https://learningcatalytics.com/) was also trialled in the class. The CRS allowed students to use their mobile devices (phones, tablets, laptops) to respond to a variety of numerical, multiple-choice, short-answer and open-ended discussion questions posed both before class and during the face-to-face workshop sessions.

The main focus of the current study was to attempt to quantify whether introducing the flipped learning approach into the classroom positively affected the performance of students on their course assessment tasks. The study used learning analytics to investigate whether there was any direct correlation between the amount of time students spent studying the weekly online material and the correctness of their answers to the weekly pre-lecture and workshop questions, as well as on their final exam marks. This paper presents the initial results of the study.

1.1 Flipped Learning

The Flipped Classroom is a pedagogical model in which the typical lecture and homework elements of a course are reversed (Diaz et al., 2013). Flipping allows an instructor to provide traditional, low cognitive level, lecture materials in an alternative format outside the classroom, freeing up class time normally used to 'convey' information to students (Toto & Nguyen, 2009). Instruction that used to occur in class can then be accessed in advance of class (generally at home) so that students are well prepared and can derive the most benefit from the time spent in the face-to-face learning environment (Tucker, 2012).

Although there is no exclusive model for the flipped classroom approach, it has generally become known as the practice of providing students with pre-recorded lectures before class, and then using the classroom time to engage the students in learning activities to build on the knowledge gained from the pre-recorded lectures. Toto and Nguyen (2009) maintain that flipping lectures retains the best qualities of the traditional teacher-centred lecture model while also including the best qualities of the active learning or student-centred teaching model.

In the current study, students worked through narrated, weekly online lecture material (eLectures) prior to attending face-to-face class (workshop) sessions. Students accessed the weekly eLectures through the course homepage on the University's learning management system, Blackboard. The eLectures were recorded as Mediasite (http://www.sonicfoundry.com/mediasite) presentations and students viewed the eLectures through this online forum. The workshop sessions were then used to foster student engagement by working through typical problems, providing feedback, introducing advanced concepts, and facilitating student discussions and other collaborative learning activities (Toto & Nguyen, 2009; Tucker, 2012).

The eLectures were made generally available to the students at least one week before the workshop sessions and they were disabled again approximately two hours before the workshop sessions were scheduled to commence. This allowed students to work through and study the eLectures when and where they wanted, and for as long as they wanted. Different students learn at different rates and this arrangement allowed them to spend as much time on the material as the needed. All students need time to be able to absorb and process the information needed before it can be applied (Toto & Nguyen, 2009).

The eLectures were designed to explain the theory, demonstrate a few worked examples using the theory, and then pose a number of questions for the students to solve themselves (Figure 1). The students solved the questions and then submitted their answers on the LC website using their home computer or mobile devices (phones, tablets, laptops etc). LC provided students with instant feedback on their CRS answers so they could see how they were going before moving on to the next eLecture. In order to encourage students to utilise and engage with the eLectures, the student questions were graded.

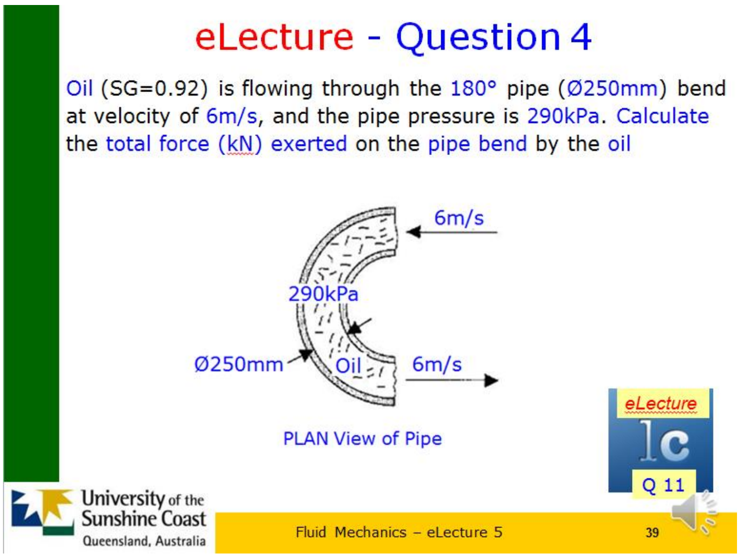

Figure 1: Typical eLecture question

Workshops extended the eLecture content by including a variety of carefully designed, engaging activities (many were group activities) that used CRS questions to facilitate discussions, problem solving and case study analysis to enhance student cognition. Students used their mobile devices to respond to the CRS questions posed during the workshops. This arrangement also provided opportunities to identify potential problem areas, and to enable on-going assessment and evaluation of learning outcomes. To encourage participation in the workshops, students were also graded on the correctness of their responses to the CRS questions. A maximum of 40% of the total student grade was allocated for the student responses to the weekly eLecture and workshop questions.

The CRS was also used at various times throughout the semester to survey students and obtain feedback on their experiences and feelings about the new flipped classroom teaching method. Feedback was also received via the University's normal end of semester student feedback on teaching and courses (SETAC) course evaluation instruments. The student feedback obtained through these processes provided valuable and useful insight into student perceptions of the flipped learning approach.

1.2 Learning Analytics and context of the study

Learning analytics has been defined as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Brown, 2012).

Learning analytics was used in this study in an attempt to measure the impact of the Flipped Classroom eLecture component on the student learning outcomes of the course. In order to improve the accuracy of the data collection and statistical analysis of students' learning behaviour while working through eLectures, they were recorded and accessed through Mediasite. Using Mediasite allowed precise tracking of each student's viewing activity for each eLecture throughout the course. The collected data could be presented using a variety of interactive graphs, intensity maps or playback statistics. This study used a number of useful Mediasite functions including:

- A "Who's Watching Now" dashboard that gave a real-time snapshot of which students are viewing each of the eLectures;
- eLecture analytics that showed which content was being watched, when and by whom during any given time period. Intensity maps also indicated which presentation segments were being watched most often; and
- User analytics showed a specific student's (or group of students) viewing habits over any given time period, including presentations watched, viewing activity and total viewing durations.

All of the data generated by Mediasite could be exported to EXCEL or other programs for deeper analysis through other applications and tools. Three of the Mediasite data presentation options are shown in Figure 2.

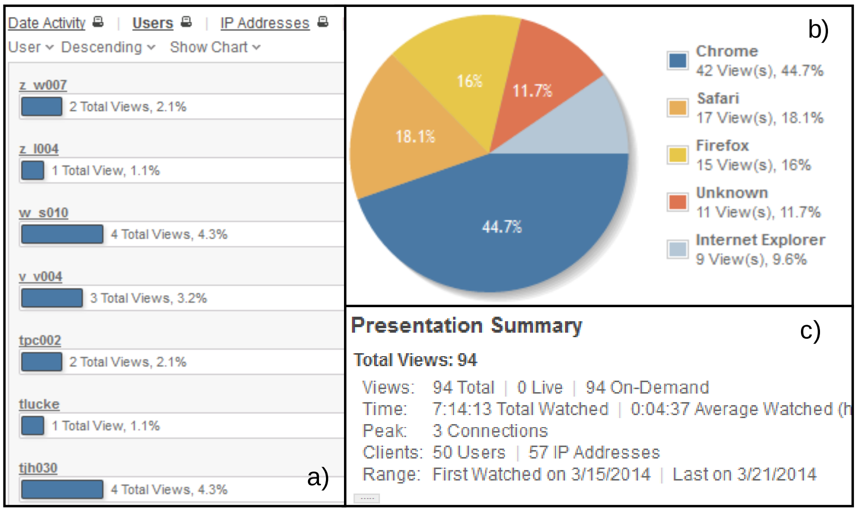

Figure 2: Various Mediasite Statistics Presentation Options: a) Views by User b) Platforms c) Viewing Summary

2 Methodology

This study used learning analytics to investigate how effective the flipped classroom approach was in producing desired student learning outcomes in a second year fluid mechanics course. The study analysed data collected by Mediasite (through the University's LMS) to determine whether there was a correlation between the total amount of time students spent on the weekly eLectures and their results for four of the summative course assessment tasks. The four assessment tasks used in the study to measure student performance were the correctness of their answers to the weekly eLectures and Workshop CRS questions (15% + 25% = 40% of final grade), and their results in the mid and final exams (20% + 20% = 40%).

Previous research (McKay et al., 2012) concluded that a student's grade point average (GPA) is a reliable predictor of their assessment task performance. This conclusion was also tested in this study using learning analytics by comparing the students' GPAs (max 7.0) to their total exam results (40%). The study also used learning analytics to investigate whether there was any direct correlation between:

- the amount of time students spent studying the weekly online material;
- the correctness of their answers to the weekly eLecture and CRS questions; and
- students' total exam results.

The data were analysed using linear regression techniques. The linear regression plots are presented as Figures 3 to 5 as listed in Table 1.

Table 1: Study Learning Analytics Comparisons

Compare	With	Figure
Student GPA at start of semester	Student Total Exam Marks (/40)	Figure 3
Amount of time spent studying the weekly online material (eLecture Hours)	Correctness of answers to the weekly eLecture and workshop CRS questions (/40)	Figure 4
Amount of time spent studying the weekly online material before final exam	Total Exam Marks (/40)	Figure 5

A range of evaluation methods were also used to gauge the effectiveness of the new teaching format in achieving increased student engagement. These included classroom observation, student surveys using LC, feedback from student emails, and results of standard end of year student evaluation instruments.

3 Results and Discussion

A number of studies (McKay et al., 2012; Elliot et al., 1999; Harackiewicz et al., 2002) have demonstrated that a student's performance in previous courses can be a fairly reliable predictor of future course performance. Most universities use some type of grade point average (GPA) ranking to measure student performance. Figure 3 compares the GPAs of the study students before starting the Fluid Mechanics course (maximum possible GPA score = 7.0), with their results in both exams (maximum grade = 40%). The linear regression coefficient of determination value (R^2) of 0.174 shows a relatively low correlation between the students' total exam results and GPAs in this study. This correlation was not as strong as has been demonstrated in previous research. Although, the result shown in Figure 3 was the highest correlation value of the three comparisons made in this study.

There can be many factors that influence performance and results from one student cohort to the next, however, and these would have to be taken into account to enable a more accurate and realistic conclusion.

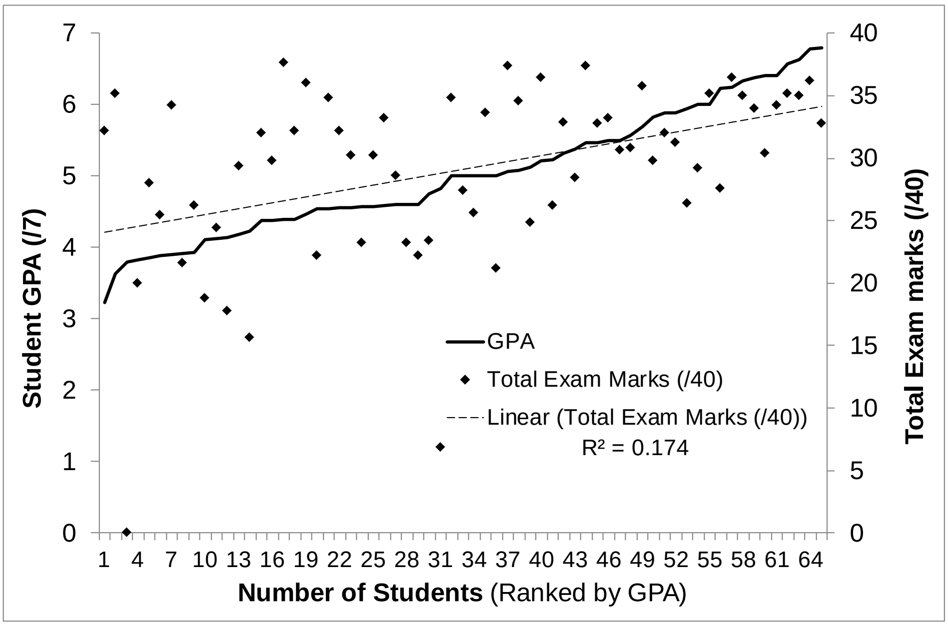

Figure 3: Comparison of student GPAs with total exam marks

All of the learning materials for the course were presented to students via the weekly narrated Mediasite eLectures. Mediasite enabled the collection of precise statistical data relating to students' viewing behaviour while working through the eLectures. Mediasite produced a detailed record of how many times a particular eLecture was viewed by students, and exactly when and how many times it was accessed.

As part of the initial study research objectives, it was hypothesised that the more time students spent working through the weekly eLecture material, the better their responses would be to the weekly eLecture and workshop CRS questions. However, Figure 4 shows a very poor correlation (R^2 = 0.0122) between the time students spent studying the eLecture material and the correctness of their answers to the weekly CRS questions.

The low result shown in Figure 4 was surprising (and disappointing) as it was anticipated that students' cognition and recollection levels would be much higher directly after learning each week's material and that this would be clearly demonstrated in the degree of correctness of student's answers to the CRS questions. However, this was clearly not the case and this could potentially have significant ramifications as to the efficacy of the flipped classroom approach. Although again, there could be many different reasons why the correlation shown in Figure 4 is so low and it is very difficult to identify the true cause(s).

One idea was that the low correlations could be that some students rushed through the eLecture material and questions "just in time", before the eLectures were disabled, in order not to miss out on the chance of getting at least some of the marks allocated for the CRS questions. The Mediasite reports showed that the peak viewing activity for the eLectures always occurred on the day before the workshop (i.e. the day before the eLecture questions were disabled) and this finding could support this possibility. However, more research is needed to evaluate this in more detail.

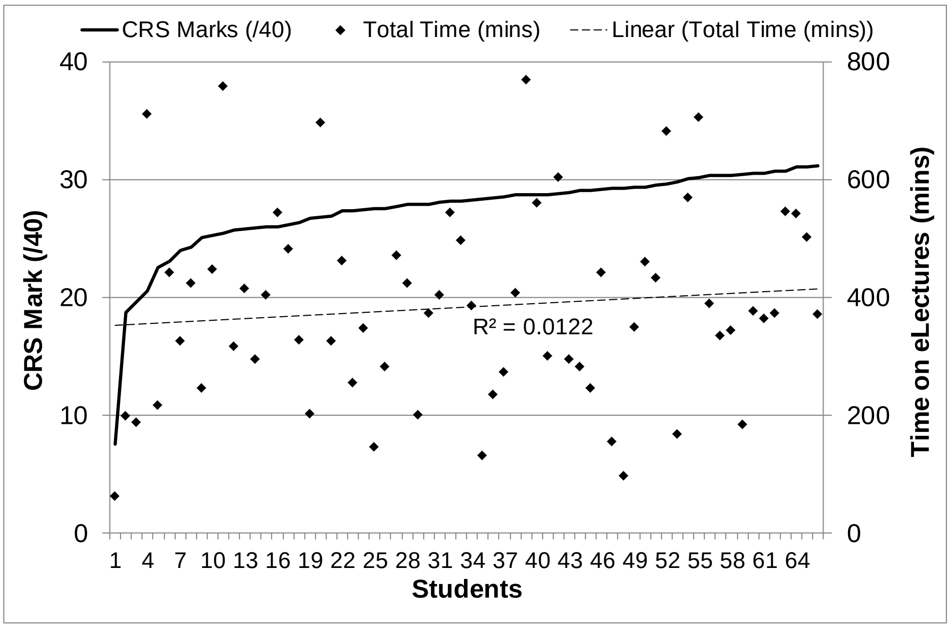

Figure 4: Comparison of time spent on eLectures with CRS question results

Research has shown that all students need enough time to be able to absorb and process information before they can apply it (Toto & Nguyen, 2009). While providing students with learning materials and enough time to work through and absorb it all before lectures is a good idea in theory, if students do not use the learning time wisely, then it may be no more effective than traditional teaching practices. In fact, it could potentially be worse for students if they rush through the materials the night before the lecture just to get up to speed as this could result in superficial learning only occurring (Marton & Säljö, 1976; Biggs, 1987).

In time, it may become evident that flipped learning is only more beneficial and effective than traditional teaching practices if students actually utilise the time available to them before lectures wisely. For the flipped learning model in particular, students really need to work through the pre-lecture material properly in order to fully learn it and understand it. Otherwise, they may perceivable be worse off than with a more traditional teaching and learning approach.

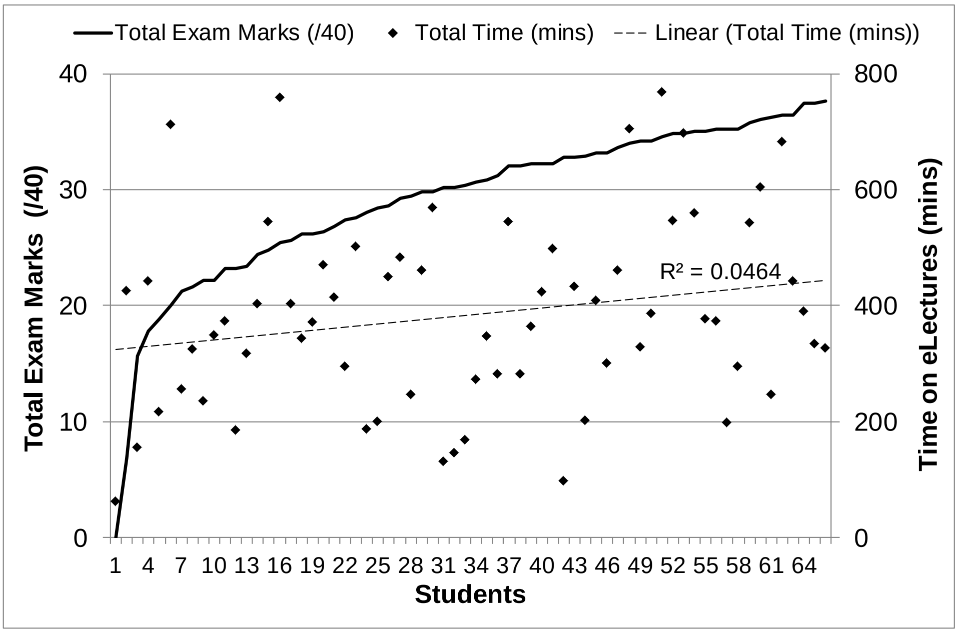

Figure 5: Comparison of time on eLectures with total exam results

In order to evaluate whether the total amount of time spent on the eLecture materials affected student performance in their exams, these variables were also compared. Again it was hypothesised that the more time students spent studying the weekly eLecture material, the better their performance would be on their mid-semester and final exams.

However, Figure 5 shows another poor correlation (R^2 = 0.0464) between the total time students spent studying the eLecture material (up to Week 13) and the correctness of their answers to the questions on the two exams (held in Weeks 6 and 13, respectively). These results were also unexpected and potentially disappointing with respect to the efficacy of the flipped learning approach used in this study. Again, further research is needed to investigate the actual causes of this relationship in more detail.

The CRS was also used to survey students on their perceptions of using the new technology and to gain a deeper understanding of how its use could be improved. At various times during the course, a number of evaluation questions were posed to obtain student feedback on the new flipped classroom teaching method for evaluation purposes. The CRS was also used to obtain information on technical issues, such as which internet browser or phone provider the students were using or how they found the registration process and similar logistical queries. Figure 6 shows four of the CRS evaluation questions asked in Week 5. The student responses for each question are also shown in Figure 6.

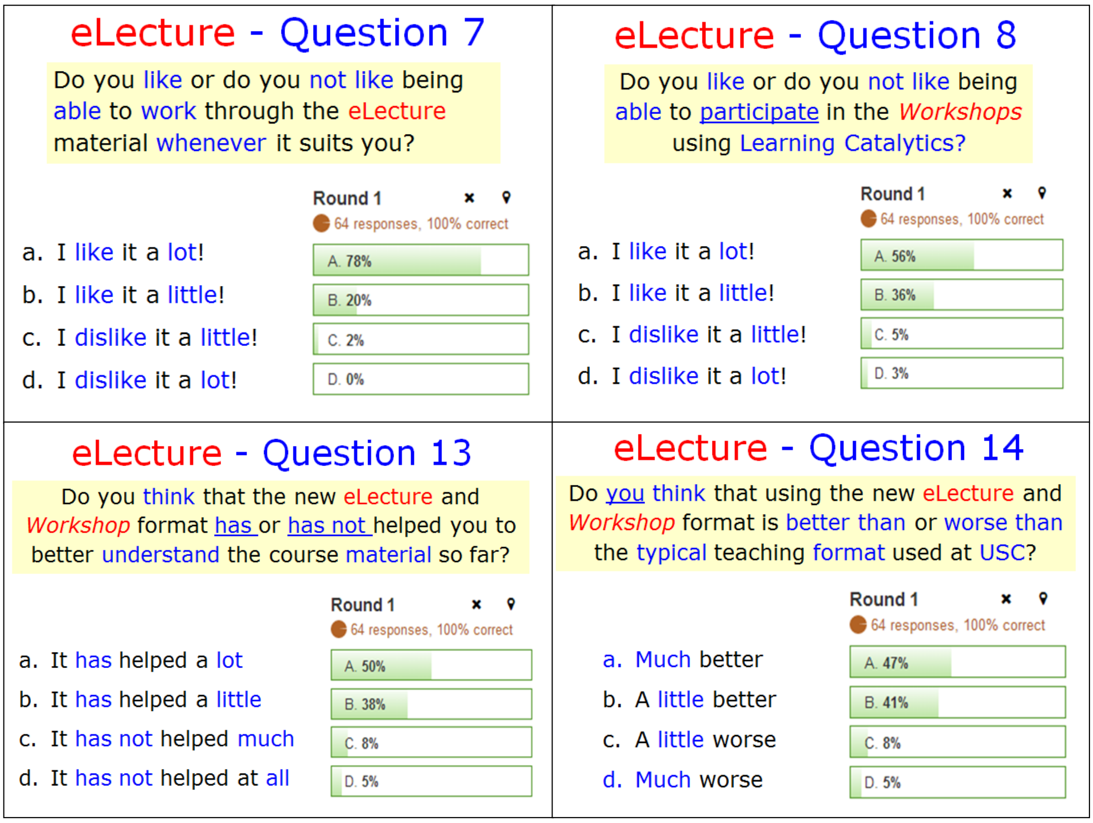

Figure 6: Four of the Week 5 evaluation questions and responses

As shown in Figure 6, between 88% and 98% of students surveyed (n=64) provided positive responses to the various CRS evaluation questions about the new Flipped Classroom learning method. This was very encouraging, particularly as most of the students had never experienced the flipped classroom before and this was only five weeks after they had first been introduced to it. It can also been seen in Figure 6 that one or two of the students also said that they didn't like the new Flipped Classroom method much. Another benefit of the reporting system included in LC is that it is very easy for the instructor to see which students are responding to the CRS questions and what their responses are. As it turned out, the couple of students who provided negative responses to the questions in Figure 6 also provided negative responses for all of the other CRS evaluation questions posed that day. Their answers to most of the workshop CRS questions asked that day were also wrong. Perhaps they were just having a bad day?

Table 3 lists a small sample of student responses to one of the open-ended feedback questions included in the University's standard end of year student evaluation of teaching and courses (SETAC) surveys.

Table 3: Sample of student open-ended SETAC responses

Q3.1) Aspects which were done well and which should be continued
• I really enjoyed the LC part of the course. It enabled me to go ahead and review the lecture content more than once to help reinforce what was being taught. And each week's lectures gave a good foundation to the workshops where that knowledge could then be expanded upon.
• LC was a great method of learning at your own pace at home. It also makes you learn the course content each week, and then by applying it the next day it cements the knowledge learnt.
• Really enjoyed the eLectures and online assessments... They really helped me gain a full understanding of subject material
• The short online lectures (eLectures) each week were very beneficial and I found them to be much more useful then a standard lecture.
• The way the course was delivered was excellent. I particularly liked the eLectures and subsequent question format, which I think really helped me understand fluid mechanics.
• eLectures are very helpful and an excellent way of learning the material (It is not possible to pause or rewind an actual lecture).
• The whole course outline was perfect. This is the way i would like all my subjects to be taught. No more boring lecture, finally a way that keeps my engaged and wanting to learn. Really enjoyed the working style wouldn't change a thing.

Student feedback on the flipped learning method was overwhelmingly positive and the results shown in Figure 6 and Table 3 clearly demonstrate how much students enjoyed the new teaching and learning approach. Evaluation results demonstrated that the new flipped lecture and CRS teaching format produced a substantial increase in the level of student engagement, motivation and attendance compared to previous cohorts (Toto & Nguyen, 2009; Demetry, 2010; Bakrania, 2012). However, while it was evident that students embraced and successfully engaged with the new flipped learning approach, this did not appear to translate into significant improvements in student cognition or deeper learning (Marton & Säljö, 1976).

Although the final student grades for this cohort were slightly higher than in previous years, this result was thought to be more due to the relatively high marks allocated the CRS assessment questions (40% of final grade) than due to the results of implementing an effective flipped learning model. Students often worked in groups to solve their CRS questions and this probably increased the collective average student grades. New weightings for the course assessment items will be introduced in future to try to reduce this effect.

While this initial study has produced some interesting and thought-provoking results, it must be recognised that these results must be viewed in their proper context. Statistical data collected through online monitoring software can be inherently variable and unreliable in nature, so any conclusions drawn from analysis of this data must be viewed correspondingly. There are many variables that could influence the results from one student cohort to the next and these would have to be taken into account to enable a realistic comparison.

This was the first time that this new teaching method has been trialled and the inconclusive nature of the results could be attributed to the preliminary nature of this case study. The study is on-going and it is expected that as more data becomes available, this will allow a comprehensive analysis to be undertaken on the pedagogical benefits of this new teaching format.

Although the results of this initial study are generally inconclusive, and do not either clearly prove or disprove whether the Flipped Classroom approach was any more successful than traditional teaching approaches, the study has clearly demonstrated the intrinsic value of learning analytics as a tool to monitor student learning behaviour. The study also clearly demonstrated how much students enjoyed and embraced the flipped classroom teaching and learning approach.

4 Conclusions

This study used learning analytics to investigate how effective the flipped classroom approach was in producing desired student learning outcomes in a second year fluid mechanics course.

A range of evaluation methods were used to gauge the effectiveness of the new teaching format in improving student engagement and learning outcomes. These included classroom observation, student surveys using CRS, feedback from student emails, and analysis of student online viewing behaviour.

The study analysed data collected through Mediasite to determine whether there was a correlation between the total amount of time students spent working through weekly online eLectures and their results for four of the summative course assessment tasks. The four assessment tasks used in the study to measure student performance were the correctness of their answers to the weekly eLectures and Workshop CRS questions and their results in the mid and final exams. The study also compared students' GPA scores at the beginning of the course with their performance in the mid-semester and final exams. The results demonstrated a relatively low correlation ($R^2 = 0.174$) between the students' total exam results and GPAs in this study. This correlation was not as strong as has been demonstrated in previous research.

It was hypothesised that the more time students spent working through the weekly pre-lecture material, the better their responses would be to the weekly quiz questions. However, the study found a very poor correlation ($R^2 = 0.0122$) between these two variables. These low correlation results were unexpected as it was anticipated that students' cognition and recollection levels would be much higher directly after learning each week's material and that this would be clearly demonstrated in the degree of correctness of student's answers to the CRS questions. However, this was clearly not the case.

In order to evaluate whether the total amount of time spent on the eLecture materials affected student performance in their exams, these variables were also compared. Again it was hypothesised that the more time students spent studying the weekly eLecture material, the better their performance would be on their mid-semester and final exams. Again, the study found a poor correlation ($R^2 = 0.0464$) between the total time students spent studying the eLecture material and the correctness of their answers to the exam questions.

The poor correlations between study time and assessment results were unexpected and disappointing and this could potentially have significant ramifications as to the efficacy of the flipped classroom approach. However, there could be a variety of different reasons for the low correlation and it would be very difficult to clearly identify the true cause(s) of this.

It was suggested that flipped learning may only be more effective than traditional teaching practices if students work through, learn and understand the pre-lecture material properly. Student feedback on the flipped classroom method was overwhelmingly positive and clearly demonstrated that students enjoyed and embraced the new teaching and learning approach. However, this did not appear to translate into significant improvements in student cognition or deeper learning.

Although the results of this initial study are generally inconclusive, and do not clearly either confirm or refute whether the Flipped Classroom approach was any more successful than traditional teaching approaches, the study has clearly demonstrated the intrinsic value of learning analytics as a tool to monitor and predict student performance and learning. While this initial study has produced some interesting and thought-provoking results, it must be recognised that these results must be viewed in their proper context. Statistical data collected online can be inherently variable and unreliable in nature, so any conclusions drawn from analysis of this data must be viewed correspondingly. In addition, there can be many factors that influence performance and results from one student cohort to the next and these would have to be taken into account to enable more accurate conclusions.

The study is on-going and it is expected that as more data becomes available, this will allow a comprehensive analysis to be undertaken on the pedagogical benefits of this new teaching format.

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A Collaborative Experience of the Industrial Area in an Academic Reality through the PBL Development

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Abstract

The present paper shows the development and the achieved results through the Methodology Techno-Cube; a pilot experience developed by the Engineering Faculty of Mondragon University which promotes a problem-based learning (onwards, PBL) based on current industry demands. Concretely, this new learning methodology involves industry within the whole PBL project; beginning with the introduction of the organizations' problematic, and ending with students' project proposals. Within this process, diverse organizations, from Gipuzkoa (Basque Country, Spain), presented their problems or necessities related to "New Business Opportunities - Diversification" and kept track of its evolution until the delivery of the project. Techno-Cube Methodology has been applied in two academic years. During the first year, the area selected to analyse was related to "smart cities", in which we prepared the different meeting points between the agents involved in the process: industries, academic experts, and local intermediate associations. However, the second experience was carried out in the thematic "people daily life", in which we focused on companies from another sectors. Thus, it allowed us to validate our methodology and to define an implementation guide. In this context, the aim of this paper is to show the Mondragon University´s approach to the implementation of an Industry Problem-Based Learning methodology called "Techno-Cube". Therefore, this paper explains the collaboration approach deployed, the industry problem-based learning process, and the methodology itself. Furthermore, the paper explores the challenges in Industry problem-based learning and the experiences and lessons learned. Moreover, this paper explores longitudinally the use of the Techno Cube Methodology, within the PBL approach, with two consecutive groups of the Master in Business Innovation and Project Management.

Keywords: Problem-based Learning; University–Industry Collaboration; Entrepreneurial Education; Entrepreneurial University.

1 Introduction

Problem solving skills are an essential part of an engineering education, due to the fact that industry hires engineers primarily looking at the workplace solving skills of candidates. On entering the workforce engineering graduates and postgraduates will deal with a great range of problems, many of them related to the need of companies to deal with new product-market challenges and the identification of product-service based new businesses.

Thus, due to its University-Industry collaboration approach and philosophy, Mondragon University has fostered the implementation of a project-based learning (PBL) approach based on current industry demands. This new learning methodology involves industry within the whole PBL project; since the introduction of the organizations' problematic, until students' project proposals.

However, in order to deal with real life problems in collaboration with industrial partners, involving a highly motivated bunch of engineering students, there are some key challenges that need to be addressed to establish a good understanding, among students, instructors and industrial partners, and assure the use of theoretical disciplines and the learning process, while obtaining industrially interesting results. One of these challenges has to do with the implementation of an adequate learning methodology.

In this context, the aim of this paper is to show the Mondragon University´s approach to the implementation of an Industry Problem-Based Learning methodology (IB-PBL onwards) called "Techno-Cube". Therefore, this paper explains the collaboration approach implemented, as well as the IB-PBL process, and the methodology itself. Furthermore, the paper explores the challenges, the experiences and lessons learned.

2 Problem based learning and the University-Industry Collaboration

From the academic approach, several factors have contributed to raising concern over problem-based learning (onwards, PBL) in higher education institutions; leading to the emergence of different approaches and educational methods, as a response for a more innovative and effective education (Bamford, Karjalainen, & Jenavs, 2012; Daly, White, Zisk, & Cavazos, 2013; Grolinger, 2011; Loyens, Gijbels, Coertjens, & Côté, 2013). This methodology is a more student-centred learning process, stressing self-directed learning, collaborative learning and learning related to practice.

In 1969, the PBL began as a revolutionary and radical approach for teaching medical students in the newly created medical school of McMaster University in Canada. Subsequently, the PBL approach was established in medical schools in the Netherlands, Australia, and the United States (Barrows, 2000). After that, this new teaching approach also spread to the teaching of non-medical disciplines such as architecture, business, construction, engineering, law, and others (Daly et al., 2013; Grolinger, 2011).

The PBL is generally described as "an instructional strategy in which students confront contextualized problems and strive to find meaningful solutions" (Capon & Kuhn, 2004). PBL confronts students with a messy, non-structured situation in which the student assumes a role or owner of the situation. Moreover, like in the real-world, the problem should not have a clear answer or solution.

The PBL is the learning of results from the working process towards the understanding and resolution of a problem in a real context. This, revolutionary and radical teaching approach, is completely different from the traditional lecture-tutorial approach as there is a shift of power from the “expert teacher” to the “student learner” (Bridges & Hallinger, 1997). In the traditional teacher-centered approach, the teacher is knowledgeable in the subject matter and the focus of teaching is on the transmission of knowledge from the expert teacher to the novice student. In contrast, the PBL approach is a student-centered approach in which the focus is on student’s learning and what they do to achieve it. In such an environment, the role of the teacher is more similar to a facilitator than to an instructor.

Moreover, in the PBL approach students take on an active role, the problem becomes their own. This personal connection between the student and the problem drives the learner to discover whatever it is; this way, they feel they need to arrive at a viable solution or conclusion to the problem.

Complementing this academic approach, Universities play an important role in the knowledge triangle. Hence, university-industry partnerships have long been realized as critical component for the successful development of a region. Furthermore, over the last few decades the university-industry partnership has gained considerable more attention, realizing that these ties are highly beneficial especially to the region, to the firms and to the academia. In this context, Universities and the associated university-industry collaboration can be crucial for the improvement of innovation competences and innovation results in Small and Medium Enterprises (onwards SMEs).

Universities are natural places to initiate, develop and maintain local collaborative academic learning programs while also maintaining other collaborations on research and development, what assures a flow of ideas and knowledge into SMEs. On the other hand SMEs need to develop broad concepts on innovation and integrate innovative knowledge; and an IB-PBL approach, could be one of the best methodologies for that.

In this context, the IB-PBL approach is a collaborative university-industry learning experience based on the problem-based learning approach focused on the company based challenges and the development of a learning project that fulfils academic criteria, all together.

3 Industry problem-based learning

MU is a young university, created in 1997 and officially recognised by Law 4/1997 of 30th May. MU has a commitment towards social transformation, which is specified in its participatory model. We are a cooperative university, part of the MONDRAGON Corporation, with a clear human vocation and a commitment to its environment, its society and its time.

As part of the University, the Faculty of Engineering (onwards, EPS-MU) has always tried to focus the whole teaching method on the students' learning process. Due to this fact, in 2002, the PBL methodology was launched for the first time through all its engineering degrees. Nevertheless, the teaching model deployed, has always tried to foster a system of relationships which, with the educational system as the central theme, aims to involve the companies and institutions in the area, in order to guarantee social accessibility, the combination of work and study, the development of research and the provision of Continuing Education. It is always has been one of the main characteristics of MU, it´s close and permanent relationship with the business world, what enables the institution to outline the educational offer by adapting it to the needs of companies, organisations and society, while transforming the society around.

Thus, EPS-MU has developed over the years an intense experience on developing PBL projects. These projects have evolved from a more traditional PBL project approach, where the students are presented with a problem scenario, usually proposed by faculty, to a more industry related problems or needs, where students have the chance to interact with businesses, shortening the gap between theory and practice (Markuerkiaga, Errasti, & Igartua, 2013). The latter PBL approaches involve industry within the whole PBL project; since the introduction of the organisations' problematic, until students' project proposals.

This approach has helped students refine their soft skills in addition to a deeper understanding of their technical, creative and managerial skills, in an industrial environment full of technological and market uncertainties. Therefore, this IB-PBL approach gives students an opportunity to develop and apply a range of experiences which will prepare them to contribute to the needs of companies.

Currently, this new methodology is being applied into different courses and intends to provide each student with "three core competences": i) technical skills that will help students on their future technical daily duties; ii) methodological knowledge focused on project planning and development; and finally, iii) "soft skills" in order to improve their integration at work, team working with colleges and customers, effective communication, problem solving, creativity, etc..

One of the key factors for the success of a PBL approach is to connect it with the real world; and actually this is one of the most difficult conditions to achieve. In most of the cases, PBL approaches are scenario-based where students are given a particular scenario by teachers, which is as similar as the traditional educational style. It is seen that the PBL model to bring up an adaptive expertise have to be real situated. With the aim of solving this gap, EPS-MU has established and IB-PBL approach where a company is involved in the PBL project, by identifying a business challenge that needs to be achieved.

This IB-PBL has two main objectives, as follows: i) to develop an answer to a company based challenges and ii) to develop a learning project that fulfils academic criteria.

4 The Techno Cube Methodology

The Techno Cube Methodology is IB-PBL methodology focused on answering to company based challenges related to "New Business Opportunities – Diversification" aimed to reinforce the university industry relationship and at the same time, promote the entrepreneurial values and training in business skills among students.

The experience is designed considering the participation of the students of the Master in Business Innovation and Project Management from Mondragon University. The curriculum of these students for the second academic semester is related to innovation and entrepreneurship, and they make a semester project related to the development of a business plan for a business opportunity they have identified.

The Techno Cube Methodology is based on six main stages and each of one has a specific objective: i) Company and business challenge presentation, ii) first milestone, iii) Second milestone, iv) Final presentation, v) Final assessment, and vi) University-business feedback (see Figure).

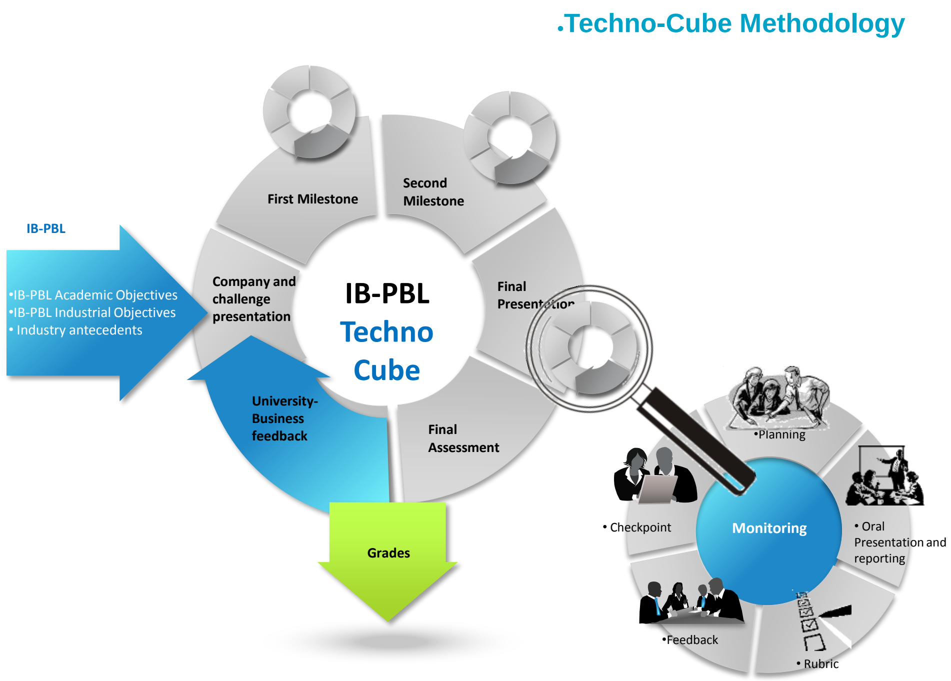

Figure 1: Techno-Cube Methodology

4.1 Company and business challenge presentation

This first phase is developed through a workshop, were companies share their insights with students. The objective of this Workshop was to identify opportunities for new businesses based on inter organizational prospective work and performed by the students of the Master in Business Innovation and Project Management from Mondragon University.

For the successful development of the Workshop, its preparation is essential, so as much as getting committed organizations interested in being part of the pilot experience. University's existing contacts are very important at this point.

4.2 First milestone

The first milestone of the Techno Cube methodology is orientated to define and show different potential business ideas developed by Master students. This milestone has the aim to focus business ideas, and to establish a competitive intelligent system that would help students and companies understand the key role of the sources for innovation, and therefore base their ideas not only in creativity activities but also in facts.

One of the key factors of this phase is the implementation of a competitive intelligent system (Gaspareniene, Remeikiene, & Gaidelys, 2013) that help students and people from companies understand and learn what's happening in the world outside their idea and business, so they can establish the best solution as possible. It means learning as much as possible, and as soon as possible, about the industry they are focusing in, the competitors, or industry particular rules. All this information will help them anticipate and face challenges head on.

4.3 Second milestone

The second milestone of the Techno Cube methodology is focused on the development of a value proposition based on the development of innovative products, services, product-service systems or processes and the design of a business model around the idea selected in first milestone.

This phase is an interactive industry-student stage, with students and people from industry, society agents and other stakeholders interact in order to test ideas, value propositions and business models.

The moodle platform of MU (MUdle) plays an important role in this phase, as students, people from industry, and other stakeholders share information and interact using this platform. The use of moodle and an enhancing tool for IB-PBL is an experience related to other experiences in literature (Sancho, Torrente, Marchiori, & Fernández-Manjón, 2011), but in a collaboration environment.

4.4 Final presentation

This milestone on the Techno Cube methodology is orientated to show the final results and achievements to business professionals, creating an appropriate environment for the University – Industry Collaboration. The final result is focused on the development of a final business model, the prototype of the value proposition, the validation of those two elements and the presentation of a business plan (Figure 2).

This phase is also an interactive industry-student stage, with students and people from industry, society agents and other stakeholders interact in order to test value propositions and business models.

The approach developed in this phase is based on the Lean Start-Up philosophy (Ries, 2011), where important attention is paid to the Customer Development concept (Blank, 2007).

Figure 2: A moment of the second milestone's public presentation

4.5 Final assessment

Given the fact that IB-PBL involve faculty members, students, and companies in the learning process, and that it is important to take into account not only the product but also the learning process, evaluation must take into account faculty and companies in both summative and formative assessment.

In this context, different types of assessment are shuffled, and rubric used as an integrator of these elements, due to their ability to make more objective the assessment (Igartua, Errasti, & Ganzarain, 2014).

One of the key elements of the IB-PBL assessment is the rubric developed to integrate the different assessment tools used. The rubric is used through the two intermediate milestones and at the last milestone (final presentation). The rubric integrates the formative and summative assessment types related to:

- Project plan
- Project report
- Market real test
- Business Model
- Prototype
- Learning outcomes by subject
- State of the art (objective data)
- Product/Service portfolio
- Business Plan
- Final group presentation for company

4.6 University-business feedback

This assessment based on rubrics is done for the three milestones (two intermediate and one final) and used for the feedback with students as well as for the final grading. The rubrics are established for each one of the milestones, as the process objectives for each stage are different. Besides, during each milestone rubric assessment, the previous one is assessed in order to show students their evolution.

Moreover, this feedback approach also helps students understand the importance not only of the result (summative approach), but of the learning process developed (formative approach).

Besides the feedback, and based on these rubrics, each teacher evaluates each student, both individually and as part of a group, throughout each milestone of the Techno Cube Methodology.

5 Experiences obtained and lessons learned

The Techno Cube Methodology is a new learning methodology based on IB-PBL that involves industry within the whole PBL project; beginning with the introduction of the organizations' problematic, and ending with students' project proposals.

Within this process, diverse organizations, from Gipuzkoa (Basque Country, Spain), presented their problems or necessities related to "New Business Opportunities - Diversification" and kept track of its evolution until the delivery of the project.

Techno-Cube Methodology has been applied in two academic years. During the first year, the area selected to analyse was related to "smart cities", in which we prepared the different meeting points between the agents involved in the process: industries, academic experts, and local intermediate associations. However, the second experience was carried out in the thematic "people daily life", in which we focused on companies from another sectors. Thus, it allowed us to validate our methodology and to define an implementation guide.

The experiences of MU in the implementation of the Techno Cube Methodology and its historical evolution refer to the identification of four key challenges:

5.1 Company understanding of the IB-PBL approach

The company understanding of the IB-PBL approach is a key element that assures that company, faculty members and students expectations are balanced.

Most of the times, companies are interested in the result itself rather than the process followed in the achievement of the IB-PBL. Companies tend to think that structuring the process has to do more with an academic outcome rather than a useful result. Therefore MU´s approach towards IB-PBL tends to underline, when planning the IB-PBL with the company, the need for both approaches.

The arguing for that has to do with the fact that most of the times, companies (most SMEs) do not have or developed an structured process when dealing with new business opportunities or diversification. Thus this complementary approach gives students the opportunity to develop an learning approach, where they can learn about the process undertaken, as well as the different tools used, providing them with an method and knowledge asset that could be used for future projects developed by their own or in collaboration with the university or other agents.

5.2 Proposed Paper Session Themes

The need to integrate a learning approach as well a result orientated project in the students´ minds in a natural and university-business collaboration approach is another key fact that has been proved to be vital for IB-PBLs.

Students tend to be influenced, and positively encourage and pushed by companies, to achieve a business orientated result. Moreover, company representatives in the project tend to change their minds through the project what causes students to adapt, and sometimes forget about the importance of the learning process, focusing only in results.

It is therefore important to support students and insist on them, and help them on embracing both approaches, and fostering students in skills like negotiation, decision making, and stakeholder management.

5.3 Faculty involvement on both learning and company based results

Overall, faculty members tend to have a more academic approach towards IB-PBL. They tend to focus on the learning outcomes related to their subjects, and the use of models, tools and theoretical elements and business strategies as part of their curricula.

However, companies do focus more on the results achieved rather than in how they were achieved, and consider that the development of academic related activities decreases the resources implemented in the project.

Thus, academic staff needs to establish a balance between academic criteria and business outcomes, in order to assure both, academic and business, results.

5.4 Stakeholders approach towards change management

As it has been stated, during all the IB-PBL process things and approaches change, due to the learning process in itself as well as the feedbacks and conversations among company, students and faculty members.

Thus, an important element of IB-PBLs is to overcome and manage these changes. In a learning project management context, change management refers to a project management process wherein changes to the scope of a project are formally introduced and approved. To do that, a cooperative approach is needed, with the participation of all members in achieving quality goals and improving stakeholders´ satisfaction.

6 Conclusions

The present paper shows the development, through the Methodology Techno-Cube; of a pilot experience developed by the Engineering Faculty of Mondragon University which promotes a "Industry Problem-Based Learning" approach based on current industry demands.

Concretely, this new learning methodology involves industry within the whole PBL project; beginning with the introduction of the organizations' problematic, and ending with students' project proposals. Within this process, diverse organizations, from Gipuzkoa (Basque Country, Spain), presented their problems or necessities related to "New Business Opportunities - Diversification" and kept track of its evolution until the delivery of the project.

The results obtained of this pilot experience are the methodology itself, as well as the quantitative and qualitative results obtained from its implementation. Thus, the overall experience can be described as satisfactory at all levels; students, professionals and academics (tutors and experts).

Hence, the academic results of the students have increased comparing with the previous ones and the qualitative results achieved, obtained through the use of a satisfaction questionnaire, are 25% better than the previous year's. The feedback obtained from the companies and professionals has been highly positive, they have seen it as an opportunity to think "out of the box", introduce new and young seeds into their worlds, and take advantage of it. They have been totally involved and they would be ready to repeat the experience in following years. Finally, academics, the group composed by tutors and experts, were impressed by the results obtained; on the one hand, the level of commitment of the students to the semester project had increased significantly and on the other hand, the academic results obtained, as well as the quality of the works presented. On the whole it can be concluded that Techno-Cube has been a really successful experience.

Besides, the experience developed in these years highlights four important challenges: (1) the important role of the company understanding of the IB-PBL approach, (2) the students focus to both results and process, (3) the faculty involvement on both learning and company based results, as well as (4) the stakeholders approach towards change management.

Finally, remark that our experience is a living experience that continues its way and that will suffer changes and improvements along with the strategic pathway determined by MU academic model.

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Introducing New Engineering Students to Mechanical Concepts through an "Energy Cube" Project

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Abstract

The objective of this paper is to describe a problem based learning module, called the "Energy Cube", offered by Dublin Institute of Technology that is designed to teach mechanical, building services and manufacturing engineering concepts to first year engineering students. The Energy Cube project gives students hands-on experience in areas ranging from heat transfer, lighting and energy efficiency to industrial and product design. In the Energy Cube, students design and construct (using cardboard, clear plastic, and glue) a model of a building that admits as much daylight as possible while being energy efficient and aesthetically pleasing. The students, working in teams of four, complete most of the work within six four-hour blocks allotted for the project. Each week, students are given specific goals: (1) generate design specifications, (2) create an evaluation matrix and use it to select two preliminary designs, (3) choose one final design and make detailed construction drawings, (4) construct the final model, (5) test performance of models and record results, (6) submit and present a final report that includes recommendations for improvement. Performance tests determine what percentage of available ambient light reaches the interior and how much heat (generated by an incandescent light bulb) is retained over a 30-minute period. Quality of construction is measured using an air tightness test. The teaching team, comprised of engineering and design educators, assesses aesthetics subjectively. Individual contributions are evaluated using attendance records and peer assessments. Student feedback, via a survey, was positive regarding teamwork and team-building. It also showed a good balance among the diverse learning outcomes.

Keywords: problem based learning; design and build; peer assessment; project based approach; energy engineering.

1 Introduction

This paper is geared toward engineering educators who wish to provide students with hands-on approaches to learning mechanical engineering concepts such as heat transfer. The paper describes the mechanical engineering design project module taken by first year general engineering students in the Dublin Institute of Technology. The module is intended to give the students a broad introduction to concepts and methods used in mechanical, building services, manufacturing and design engineering.

This paper, authored by the lecturers who organized and taught this project in its first year, begins by introducing how the module fits into the broader engineering programme. We describe overarching objectives of the module. Next, we provide a week-by-week description of the module's content. We explain our methodology for assigning marks and note how this aligns with intended learning outcomes. We then analyse and present feedback from the students regarding their recommendations for change, satisfaction with the assignment, and what they believe they learned.

The overall Engineering Design Projects module, of which this project is a major component, adopts a Problem-Based Learning (PBL) approach. Galand *et. al*. (2012) indicated that PBL can be effective in engineering education, particularly for the application of principles. Chua (2014) found that a hybrid PBL-lecture model produced better performance with first year students. He posited the explanation that *"they may lack the problem-solving and interpersonal skills needed to participate in full-fledge PBL sessions"*. Strobel and van Barneveld (2009) found that PBL proved more effective for long-term retention of knowledge. A study by Yadav, Subedi, Lundeberg, and Bunting (2011) involving 55 electrical engineering students found learning gains among PBL students to be twice those of students in the control group (who were taking traditional lecture courses). The authors felt when devising this module that the enhanced student interaction and the opportunities for self-expression that PBL affords combined with some aspects of traditional lecturing (e.g., teaching heat transfer calculations) would give students a positive insight into mechanical and design engineering.

1.1 Common First Year for Engineers

All students entering the honours Bachelor of Engineering programme at our institution complete a "Common First Year" core of modules that includes an Engineering Design Projects module that spans the year and involves three team-based design projects. The module participants meet for four hours weekly.

This Common First Year programme, initially delivered in the 2014-5 academic year, is intended to help students select a specific engineering discipline at our institution. The Common First Year is delivered by a group of engineers, mathematicians, and scientists. The overall curriculum for the Common First Year helps students:

- Achieve a foundation in physics, chemistry, mechanics, computing, and mathematics
- Gain experience identifying, formulating and solving engineering problems
- Begin to understand the engineering design process as a system
- Develop ability to analyse and interpret data
- Develop an appreciation of professional ethics and a sense of professional responsibility (socially and environmentally)
- Work effectively as individuals and teams
- Develop communication skills of use in engineering and across society

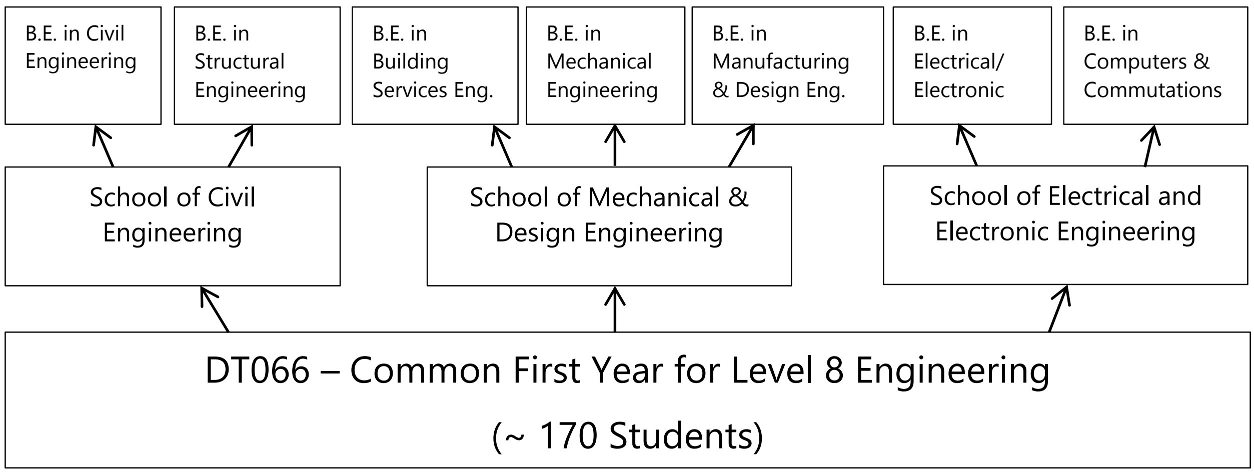

Figure 1: Structure of Level 8 engineering courses served by DT066 Common First Year course

Figure 1 shows an outline structure of the Level 8 engineering courses available and illustrates how these relate to the Common First Year core. At the end of first year students choose which course they want to pursue. The design project module gives students a taste of each engineering discipline. From each school's point of view, this is a chance to persuade students to follow a career in their particular discipline.

1.2 Engineering Design Module

After completing the Design Projects module, students should have demonstrated the following learning outcomes, being able to:

- Operate effectively within design teams
- Apply engineering concepts and design tools to solve engineering problems
- Solve problems by following appropriate specifications and standards
- Communicate results, verbally as well as graphically
- Recognise the social role engineers play and understand relationships between technology and society
- Produce solutions to basic engineering problems using graphical methods

- Distinguish the roles various fields of engineering play in the overall profession of engineering

2 The Energy Cube

As illustrated in Figure 1, the School of Mechanical and Design Engineering provides one of the possible paths for students at our institution. It contains the specific fields of Mechanical Engineering; Manufacturing and Design Engineering; and Building Services Engineering. The Energy Cube project gives students a taste of each of these inter-related fields. Previously the Energy Cube project was offered by the Department of Building Services Engineering. To meet the goals of the Common First Year, that module was adapted to incorporate aspects of mechanical and manufacturing engineering.

As part of the new first year curriculum, the Energy Cube assignment asks students to design and build a model of a proposed headquarters building for a multinational corporation. Students are given a design brief that requires the building to be at least 55000 m^3, modelled at a scale of 1/100. A minimum of 30% of the overall wall area must be glazing. The building should be designed to be as energy efficient as possible. It must make maximum use of available natural light and be aesthetically impressive. Students are advised that, for testing purposes, their models must be at least 200mm high and have a 100mm x 100mm hole in the floor to permit access to the testing equipment.

Each group is allocated a fixed amount of time and material to complete this design project. Each team is given: 2.85 m^2 of corrugated cardboard sheet comprised of 6 x 780 mm x 610 mm sheets, 20 clear plastic sheet (A4 sheets), and glue. The materials are analogous to the budget of the project; if a group requires additional material marks are reduced (5% for each additional sheet of cardboard used).

2.1 Week 1: Team Building and Introduction to Design

In Week 1, groups take part in a series of icebreakers to encourage teamwork. These exercises include a series of word games and a competition to build a paper aeroplane and see which can fly furthest. The groups are then provided with the project brief and given an introductory explanation of accepted design processes. Each team develops a design specification document and agrees on a set of evaluation criteria and measures. Lecturers emphasize the importance of the weekly team meeting and show basic project management tools. They provide templates that can be used for submitting the required design specification document, evaluation matrix, and weekly meeting minutes.

In Week 1, the objective is to set up a working relationship between the various team members. Teams have been chosen by the lecturers, with consideration given to distribution of gender, ethnicity and ability. We refined this approach during the course of the year in response to the phenomenological interviews conducted by the educational researcher on our team. In composing teams, we aimed to achieve diversity without leaving any single student isolated within the group. Because of the small number of females in the programme, we tried to place each girl on a team with another girl. We also tried to make the teams ethnically diverse, so that no one from a minority group was the sole ethnic minority on the team. We aimed for each team to have student from the top, middle, and bottom of the class with regard to past performance in engineering (as per Oliver-Hoyo & Beichner, 2004). We found that it was easier to accomplish once the students had been enrolled for a semester.

2.2 Week 1: Design Choice and Technical Analysis

In this session teams brainstorm ideas. They devise many different configurations and then use the design criteria developed in Week 1 to evaluate choices and determine which strategies are most likely to succeed. The lecturers give a short description of how to calculate the rate of heat that will be lost from an Energy Cube. To do this, teams are encouraged to calculate the U-values of all the different surfaces: floors, roofs, walls, and windows. Lecturers distribute a workbook that the students can use to calculate the steady-state temperature inside the cube in a methodical way. Using this heat-loss information alongside their evaluation matrix, each team begins whittling the possible design choices down to two.

2.3 Week 3: Final Design and Drafting

This stage of the project involves reviewing design choices within each team and determining the optimal approach. Teams then produce dimensioned construction drawings. They are also encouraged to compile a step-by-step construction plan to help maximize the four-hour construction period in the following week. Each team prepares final predictions for their cube's thermal performance. These predictions will be used as a point of comparison in Week 5, during performance testing. They are also used in each team's analysis of the test results and its final report and formal presentation.

2.4 Week 4: Build

The build is compressed into a single four-hour session (with a bit of grace time granted at the start of Week 5 for final touches). Having a fairly strict time limit means that the process must be planned in advance in order to make best use of the time available. Teams are encouraged to plan tasks so they can be performed in parallel, and then these separate parts can be assembled at the end. Brevity also needs to be taken into account at the design stage when considering the complexity of a design. This means that some groups default to a simple box design. We have observed that it can be difficult to complete a two-layer cavity construction in the available time. Nevertheless, groups that plan carefully are able to accomplish complex designs within the four-hour block, as illustrated in Figure 2.

Figure 2: This team executing complex design for a geodesic dome within the four-hour period

2.5 Week 5: Testing

In Week 5, tests of thermal efficiency, lighting, and air-tightness are performed on the completed Energy Cubes. The thermal test consists of putting a 100-watt incandescent light bulb into the Energy Cube as a fixed output heat source. A thermocouple is inserted into the side of the energy cube about half way up. The cube is then left to reach a steady state while the students record the temperature every five minutes. The final temperature inside each cube, as well as the ambient temperature, is then recorded by the lecturer.

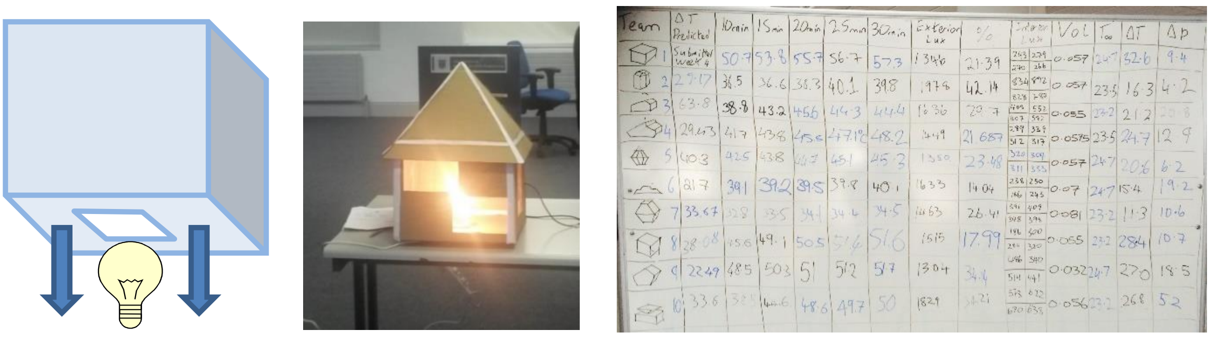

Figure 3: Energy Cube thermal test with results recorded the old fashioned way

In the lighting test the Energy Cube is placed on top of a light meter and rotated through four points of the compass and the light level recorded. The average of these four measurements is taken. Then the Energy Cube is removed and the exterior light level is measured. This aspect of the assignment can be honed in future years to take solar orientation into account during the design phase and reward good solar design during testing. This requires a more complex measurement system than we currently have in place, however.

For the final test, each cube is placed over a computer fan and a manometer is used to measure the pressure difference between the interior and exterior of the cube. This measure of air tightness is used as a metric for construction quality. The students record performance data on a whiteboard (as shown in Figure 3).

2.6 Week 6: Presentation

In the final week of the course each team makes a ten-minute oral presentation of its project for the lecturing staff and guests, who together represent the customer. Every team member is involved in the presentation. A designated team leader presents an introduction at the start and each member presents his or her contribution to the project. This is followed by conclusions and recommendations along with a reflective summary of the experience of working together as a team on this design project. To conclude the session, questions are presented to each team at the end of its uninterrupted presentation. Each team, as a group, provide a single written peer assessment of each of the other teams' content and delivery. The student evaluations are used in determining the overall presentation mark (as described below).

3 Assessment

"Assessment is integral to the overall quality of teaching and learning in higher education" (CSHE, 2014). With this in mind, the designers of this project assignment gave considerable effort to developing assessment methodology.

Marks are awarded to the each of the teams under the following headings: Design Specification & Evaluation Matrix (10%), Thermal Efficiency (20%), Thermal Prediction Accuracy (5%), Lighting (15%), Build Quality and Aesthetics (10%), Presentation (20%), and Report (20%). The presentation mark takes into account assessments by peers (20%) (see Figure 4) and lecturing staff (80%).

Peer Assessment Evaluation for Group: *(Circle number of the group that is presenting)*

__1__2__3__4__5__

__6__7__8__9__10__

Student Names:____________________

Please complete Figure 1 by 'ticking' the appropriate box. For example: a tick in the extreme left-hand box means that the statement on the left is true and is of 1+ (90%) quality. The boxes from left to right are abbreviated by:

EX = 90% - Outstanding VG = 75% - very good

G = 65%- Good OK = 55%-adequate

P = pass – 45%-Poor F = fail – 30%- very poor

Please add some general comments and feedback in the space at bottom of the page

	EX	VG	G	OK	P	F	
Content (65%)							**Content**
Objectives achieved							Objectives not achieved
Topic covered in depth							Superficial treatment of topic
Logically developed argument							Rambling; lacking continuity
Accurate presentation of factors							Much questionable/inaccurate issues
Good demonstration of key concepts							Lack of demonstration of key concepts
Presentation (35%)							**Presentation**
Attention-grabbing introduction							Uninspiring introduction
Convincingly argued							Argument lacks credibility
Clear and effective use of PowerPoint (inc. figures/tables)							PowerPoint use unclear and ineffective
Reasonable length							Too long/short
Animated tone							Flat or stilted or nervous tone

Figure 4: Peer-Assessment Rubric for Team Presentation Session

For purposes of marking, thermal efficiency is evaluated from the temperature difference (ΔT) between the interior of the energy cube and the room. The highest ΔT (ΔT_{max}) gets 15% and other teams get $(\Delta T/(\Delta T_{max})*15\%$.

Lighting is measured by dividing the interior Lux level by the exterior Lux level. The highest gets 15% and the rest get the same fraction as for the thermal test. Finally the percentage error in the predicted temperature is calculated and this fraction is subtracted from the maximum 5%. Construction quality is assessed from the pressure test results and aesthetics are judged subjectively by the lecturers.

With regard to individual contribution, Boud and Falchikov (2005) note that self-assessment helps equip students for life-long learning. The questionnaire completed by each student, in a place separate from their team members, required each student to evaluate the performance and contribution of each team member (including their own). Three categories were used for evaluation: Teamwork, Design Process, and Work Output. This exercise not only provided the opportunity for allocating individual marks, but also prompted students to reflect on the learning outcomes of the module. Gibbs (2009) concluded that giving one single overall mark to all members of a team often leads to 'freeloading' which means that the potential benefits of group work are lost and that students may feel their marks are 'unfair'. He encourages using secret peer assessment because it "produces a greater spread of marks and more distinction between individuals" (Gibbs, 2009, p. 9).

We generated each student's individual mark by applying a correction factor based on the results of the peer and self-assessment 'audit' conducted in Week 6 prior to the formal presentations. Our correction factor was weighted to reflect student attendance records.

Orsmond and Merry (2013) looked at high performing with non-high performing students and compared their treatment of feedback. They concluded that feedback should be designed to encourage development of students' self-assessment practices. Our team attempted to foster this type of development. Engaging the students in peer-to-peer learning by means of each team assessing other team's performance attempts to enhance their learning experience, and yield metacognitive gains (Toppings, 2005, p. 640). A rubric used within our College is shown in Figure 4. This instrument (by O'Dwyer, 2012) was influenced by the work of Freeman (1995). We supplied it to each team in Week 5, which prompted teams to pay attention to what was happening during the presentation session. It also provided guidance on what was expected, which supports the findings of Toppings (2005).

4 Analysis of Results of Feedback Survey

A short survey was distributed to students on the last day of the module to assess the level of satisfaction the students had with their group experience and also to assess the level of knowledge about engineering gained from completing the project.

Students expressed a high level of satisfaction (>= 70%) with their groups and their role within their groups. The results suggest that the team building exercises were worth dedicating a significant fraction (1/6th) of the total time to. This is the same amount of time allotted to building the Energy Cube (which open ended survey responses suggested the students would prefer have more time to complete). However the relatively short amount of time available for the build means that teamwork is vital and tasks must be carefully planned (e.g., planning tasks to run in parallel).

The survey also sought feedback about what students felt they learned about engineering and what skills they developed during the module. The students valued two key transferrable skills highly—teamwork and problem solving—and they indicated they learnt these in the project. The students felt they had learnt the ability to perform heat loss calculations while possibly not regarding it as a core skill. Open ended responses suggested that some would have preferred a more 'mechanical' project such as something in the automotive or aerospace areas despite the fact that these constitute a small section of the engineering industry in Ireland. By contrast, manufacturing and building services engineering represent a much larger section of the industry here. The gender distribution is as encountered in all too many engineering courses.

	Strongly Agree	Agree	Neither	Disagree	Strongly Disagree	Sample Size
The work was divided evenly between members of the team.	16.5%	60.4%	11.5%	7.2%	4.3%	139
I felt I was listened to in my group.	36.2%	55.3%	5.0%	1.4%	2.1%	141
Other members contributed equally to the team.	22.7%	51.1%	12.1%	9.9%	4.3%	141
I felt I played a valuable role within our group.	28.6%	57.9%	12.9%	0.0%	0.7%	140
I feel more confident working in teams than before.	27.1%	32.9%	33.6%	5.0%	1.4%	140
I have a better idea of what engineers do.	12.9%	52.1%	26.4%	7.1%	1.4%	140
I feel more confident that engineering is for me.	25.7%	42.1%	28.6%	2.9%	0.7%	140

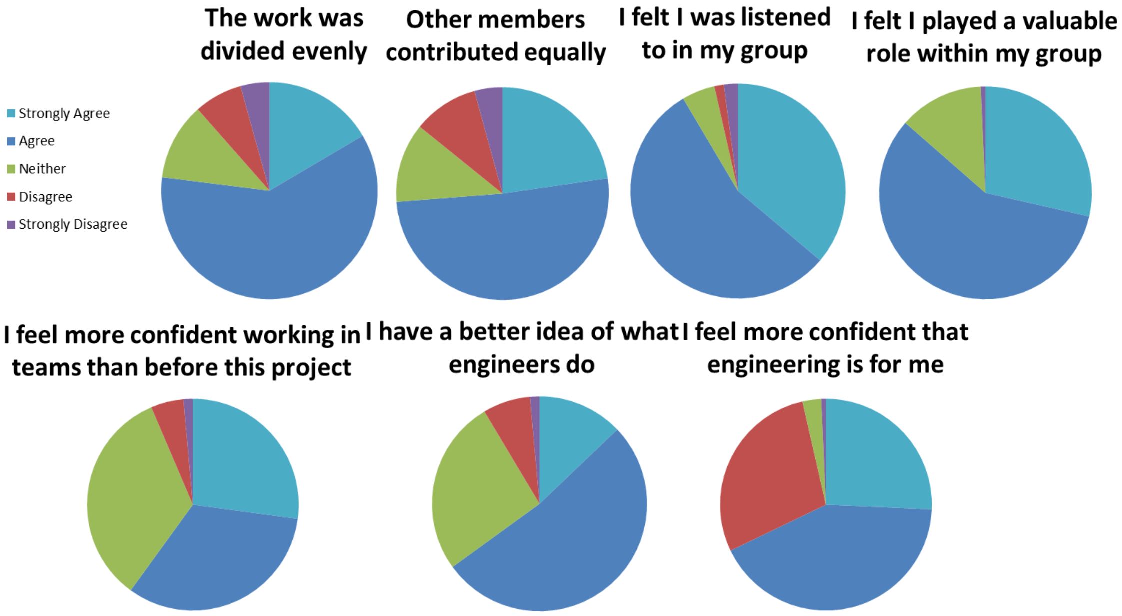

Figure 5: Student feedback on teamwork and knowledge of engineering gained during the course

	Drawing & Graphics	Heat Loss Calculation	Team Work	Problem Solving	The Design Process	Communicating Results	Valid Sample Size
Which of the following topics we covered do you feel will be most useful to you as an engineer?	11.5%	10.0%	31.5%	29.2%	15.4%	2.3%	130
Which of the following skills do you feel you learnt?	9.2%	22.9%	26.7%	21.4%	16.8%	3.1%	131

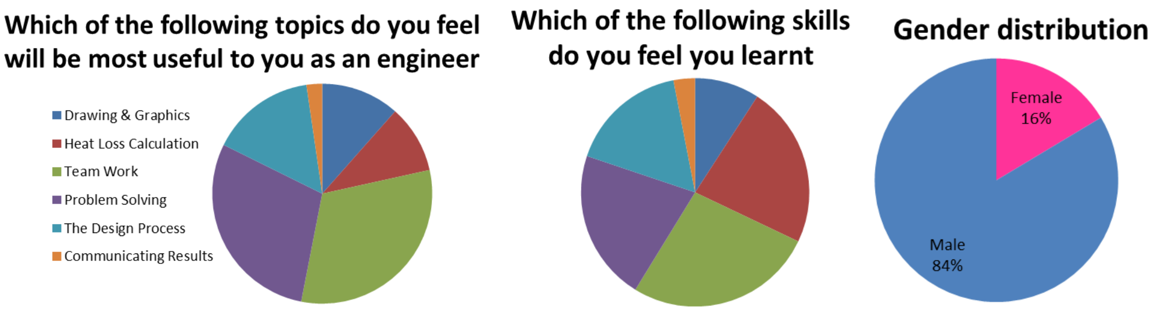

Figure 6: Student feedback on learning outcomes and class gender distribution

5 Conclusions

A design-and-test project has been described in this paper. It requires students to build a model of an energy efficient, aesthetically pleasing structure that makes maximum use of available light. It provides students with experience in mechanical, manufacturing and building services engineering. The content of the module has been described in chronological order.

A breakdown of the assessment of student performance has been described including a description of the peer assessment used. Finally, an analysis of the student survey data has been presented. Overall, the students appear satisfied with the teamwork section of the module. They felt it improved their knowledge of engineering while leaving and covered a range of the designated learning outcomes for the course.

The module provides a way for students to learn about the critical importance of energy efficiency, in particular in buildings, and how we have a responsibility to make buildings and processes as energy efficient as possible. They learn about the ways that energy is wasted and develop ability to quantify these aspects of design. They learn how good design leads to a good final product and that planning is essential. Finally they learn how energy efficiency can be designed into a building, machine, or process.

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Active Learning of Useful Mathematics in Engineering Education

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Abstract

Mathematics is becoming prevalent in the modern world and provides valuable tools for a variety of engineering professions; nonetheless, its abstract notions make it difficult to teach especially in the digital world. Numerous studies about problem-based learning have demonstrated that mathematics is not very suitable for the said method because of its theoretical content. And thus, many training which practice widely the active teaching method, however, have recourse to lecture-based teaching for mathematics. While, excluding the fundamental sciences from the attractive learning method will not solve the problem of demotivation of students and will seriously affect their training. Consequently, many questionings have been raised about the way to teach mathematics to engineers which training is mainly based on projects and multidisciplinary problems. We, thus, have decided to change our courses so much about the form as the content by shifting from a classic course to team based learning. First, through the establishment of a team learning method, a dynamic teaching method where students can exchange ideas and help each other and also through a shift from classical course to problem-setting course which meet needs of other teaching subjects and at best meet those of the professional life and real world.

Keywords: mathematics courses; team based learning; engineering curriculum.

1 Introduction

Mathematics are essential for the training of an effective engineer (S.S.Sazhin, 1998), it helps develop skills such as reasoning, rigorousness and responsiveness. On the other hand, its abstractness can somehow demotivate students who deem mathematics useless in their upcoming professional life. Consequently, adopting a new methodology, which is simple, motivating and interesting has been a significant challenge these past two years at ESPRIT (Marilla Svinicki, 2005-2006). Besides, while reviewing the form, the content and the objectives of our courses, we have encountered numerous difficulties to apply the active learning pedagogy in basic mathematics courses. In fact, once the engineering specialty subject is selected, a set of interdisciplinary projects meeting corporate expectations are developed using precise mathematical tools. The learners will be extra-motivated because they have to solve factual problems. Our new experience is to combine effective practice and teamwork on so many levels (C. Rabut). Team-based learning approach produced spectacular results in terms of learning performance, motivation levels, attendance records as well as engineering skills.

2 Reasons of changing method

"The only person who educated is the one who learned how to learn and change". Carl Rogers

The conceptual aspects of mathematics is far from being motivating for students since the latter feel the need to deal with practical material, a material which will help them to get familiar with professional life. In fact, all scientific, technological, financial and management fields are essentially based on the ever-rising power of computers and software that go with: more and more complex mathematical tools via computer in companies are used this way. This fast-paced general trend requires an evolution corresponding to engineers training. It was considered as essential to focus on teaching of mathematics in engineering schools and to analyze the relationship between that teaching and computer due to the great development of the digital simulation. It seemed also useful to examine the behavior of the future engineers namely the interest that has shown in the mathematics courses and the difficulties that may encounter for the good assimilation of notions often perceived as abstract and difficult to deal with.

Engineers' training particularly demanding mobilizes inevitability in students, several skills of different nature. It effectively requires the use of mathematical tools for dealing with problems with abstract notions, difficult to apprehend and identify. In other way, the student must be able to articulate intuition and rigor. Those dual skills are important for the student, that's why the mathematics course in Engineering School is of enormous importance.

It is obvious that the traditional course has turned out inefficient in the development of skills of engineering student. It thus becomes paramount to find a methodology focusing on problem-solving based teaching that effectively develop not merely students' knowledge but also their skills.

Our pedagogical project has been implemented in order to reduce the passive attitude of students in mathematics courses and to share messages in good agreement with practice. We are convinced that this discipline should follow the innovative teaching method adopted by the Engineering School ESPRIT since two years which choose to apply problem or project –based learning approach to all disciplines.

3 Used tools

"The secret of change is to focus all of your energy, not on fighting the old, but on building the new".

Socrates

We thought to opt to working in groups, thus facilitating the cooperative work-based learning where students can exchange their ideas and thoughts and help others to solve problems. This new approach solves part of the problem which is students passivity but do not tackle with the difficulties of theoretical content often perceived as very difficult task. To address that challenge, an introduction of application examples in connection with engineers' professional life has been revealed necessary (S.S.Sazhin, 1998). For that purpose, we looked for problems, projects, applications and examples which resolution will help students to acquire the skills needed for their training and to get acquainted with the new fields of application in career life.

The main aim of this new pedagogical tool is to deal with the two major difficulties encountered in teaching mathematics to engineering students, namely motivation and the abstract content of lessons.

We have been thinking to opt for innovative and active teaching methods such as project-based learning and team-based learning for the teaching of basic modules.

Our approach consists of getting rid of classical courses (K.Louati, L.bettaib, and L.derbel, 2014) by shifting to problem-based and context-based courses through solving of practical situations of real life.

The used approach for carrying the course is given as follows (K. B. Naoum, C. Rabut, and V. Wertz):

- Set the objective: a discussion between teachers around a descriptive sheet of modules is necessary to define the teaching goal
- To refer to pre-requisites: it is essential to take the student old knowledge as a basis for the construction of problems.
- Define the course outline: the lesson structure organizes ideas according to their difficulty degree and enables better assimilation of new notions.
- Contextualize the different sections by problem situations: explaining the relationship between the theory and practice shows the usefulness of the notion to grab students' interest.
- Introducing reminders through little tasks if required: this enables to refresh memory without the use of a document of reference.
- Make a synthesis and draw a conclusion of the used method: at the end of each part, a summary is given to students and reviewed and reorganized by the teacher for the better reinforcement of learning skills
- Schedule one or several sessions of classical or applied tasks to replace the restructuring course.

Team Based Learning method in mathematics is carried as its name indicates through small groups of five to six students taken at random from the first session (L., Stanne, M. E., & Donovan, S. S. 1999). In a spirit of competitiveness, exchange and attractiveness, the mathematics course becomes more dynamic.

4 Learning method analysis: team based learning in mathematics courses

Our method is a mix of classical-based and innovative-based teaching method. It is based on workshops consisting of work groups where the teacher acts as an agile coach and facilitator and where students are in a dynamic of competitiveness (Michael Prince, 2004). The aims of the course have been established beforehand by the teacher on the basis of pre-requisites. Simple recall is often given where necessary in the form of integrated practice tasks throughout the project.

Before we deal with our learning method, it is important to take a look at the main differences between a teacher and a TBL tutor, a teacher is defined usually as an instructor who provide tuition to a large number of students ,they are required to follow standardized curriculum focused within a specific academic standards, unlike TBL tutor ,traditional teacher use subject-centered courses where teachers will have to provide learning materials and a method that fits most students, whereas TBL tutor prime role is to facilitate the TBL process by keeping the group focused on tasks ,and guiding them to achieve their goals. In an ideal world, teachers and tutors would complement each other.

In fact, our choice in combining innovative based teaching style with traditional 'pedagogy" style was clearly not in random, since the tutor in its new role of facilitator in monitoring individual process and motivating group, will not cease to ensure the role of the traditional teacher who must be able to make a recall of prerequisites of notions that may seem essential to effective process learning.

Our project focuses on two basic principles namely context-based and cooperative-based learning. Students work in small groups around one or several problems drawn from professional situation. We choose to opt to working in teams enabling students to acquire good communication and problem-solving skills. This new pedagogical form enhances students' personal skills and attitudes such as mind openness, self-assertion, active listening and solidarity.

While, as with any other activity proposed to students, it is crucial that the latter recognize the pedagogical reasons for teaching such a method and the relevance of working in teams in order to enhance their involvement and motivation towards this new approach. Very often, students express their frustration towards activities in groups due to the problems with way things work, related to expectations and perceptions of different members, coordination logistics and fairness assessment.

And there comes the role of the tutor who will help to guide students not only in terms of works to perform but also to the way to proceed in team. He must clearly define working benchmarks in groups and enable effective and organized cooperation. It is necessary; he/she establishes the criteria of performance and success. Its basic functions are to supervise, animate and support work in team. Through observation, class management and accomplished work assessment, he may control the activities and the tasks.

The tutor supervises the work by circulating among the groups by helping them and makes himself / herself available. He may also summarize interventions; steps completed and revive a discussion he deems necessary. He may also clarify issues and give instructions to effectively identify the pedagogical objectives.

While, we may encounter a particular difficulty in the implementation of active pedagogy device in mathematics since our concern is to see how students can successfully acquire a deep understanding of mathematical notions and not merely apply ready-to-use formulas. Often, this call for increased vigilance from the tutor to make sure that the targeted notions are clearly identified. In order to seek students' interest, we choose to vary the type of context between engineering problems, more academic problems related to another discipline, logic problems and professional-related problems. In our view, it is appropriate to vary situations in order to motivate students and get them involved and promote discussions within the group as well as to prove the usefulness of learning in real life.

Today, we can state that it is entirely possible to build mathematics' problems that fit with the active pedagogy approach (Michael Prince, 2004) and that our method remains applicable to any discipline including theory and abstraction.

5 Concrete examples

5.1 Secret sharing and linear systems

How can we send a secret message with several players in a way that they do not know the content of the message?

Typically, a secret to be shared can be presented as an integer since; a number can use encryption to replace a text. Let's imagine that we want to send the number $\mathrm{P}(0)$ where P is a polynomial of degree 2. We choose three players. The three players are provided respectively with numbers $\mathrm{P}(1), \mathrm{P}\,(2)$ and $\mathrm{P}(3)$. Once the three players arrive at their destination, then, we should be able to reconstruct the polynomial P to calculate the secret number $\mathrm{P}\,(0)$.

Let be then: $\mathrm{P} = \mathrm{aX}^2 + \mathrm{bX} + \mathrm{c}$

To determine the polynomial P, we have simply to determine the real numbers a, b and c

We give values of $\mathrm{P}(1), \mathrm{P}\,(2)$ and $\mathrm{P}(3)$ and we ask students to determine the relations verified by the real numbers a, b and c. Students are able to determine the following relations:

$$\begin{cases} \mathrm{a} + \mathrm{b} + \mathrm{c} = \mathrm{P}(1) \\ 4\mathrm{a} + 2\mathrm{b} + \mathrm{c} = \mathrm{P}\,(2) \\ 9\mathrm{a} + 3\mathrm{b} + \mathrm{c} = \mathrm{P}(3) \end{cases}$$

We introduce then the notion of the linear system

Let's now return to our main problem, we will ask students to solve the previous linear system and reconstruct the polynomial P to finally find out the secret number $\mathrm{P}(0)$. Then, students will be able to solve the previous linear system using elementary methods that have been learnt in high school (substitution and elimination) since they haven't yet acquired methods of linear algebra. This prompts us to introduce the writing matrix of linear system. We ask then to describe the previous system denoted as follows:

$$\mathrm{AX} = \mathrm{Y}$$

Where A is square matrix, X and Y are vectors to be determined by using the method of solving of first-degree equation with one unknown element. Students will be asked to solve the previous linear system after verifying that A is invertible. Students recognize that in order to solve a linear system and find a unique solution, the matrix associated to this system should be invertible. This may constitute an effective connection to the notion of inverse matrix.

In fact, the choice is made in such a way that the matrix A should be invertible. In another point of the course, we may be interested with the case where the matrix of a system is not invertible. This case will be treated using another linear algebra tool: Gaussian elimination algorithm.

5.2 Encryption and matrices

A banking agent would like to send a code in the form of two integers x_1 and x_2 to a client. Being afraid the message be intercepted, the banking agent decides to encrypt a message in the following manner:

He chooses a square matrix A of size 2 and puts $\mathrm{X} = \begin{pmatrix} \mathrm{x}_1 \\ \mathrm{x}_2 \end{pmatrix}$. He then calculates the product matrix $\mathrm{AX} = \begin{pmatrix} \mathrm{y}_1 \\ \mathrm{y}_2 \end{pmatrix}$, and sends the numbers y_1 and y_2, let's take the example:

Assume that the code to be transmitted is composed by the numbers $\mathrm{x}_1 = 2$ and $\mathrm{x}_2 = 3$, the agent uses the matrix $\mathrm{A} = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix}$, to encrypt his message. Which message will be sent to his client?

This may be done simply by computing the matrix product $\mathrm{Y} = \mathrm{AX}$. This question will be an occasion for students to review the multiplication of a matrix by a vector, a notion which is familiar to them. They will then proceed to computing and will not find any difficulty to determine the encrypted message. Having received the encrypted message, the client should be able to reconstitute the original message. What procedure should be followed? Students may think: Since we want to return to the original state, we should then go in the reverse direction of the encryption phase. The word "reverse" is then meaningful to them but they are not able yet to define the notion of the inverse matrix. We may propose the following figure "Figure 3" and ask them to complete the following property:

$$X \xrightarrow{\times A} AX$$
$$X \xleftarrow{\times B} AX$$

Figure1: Encryption and decryption

To decode a message, one should multiply AX by a matrix B that satisfies $\mathrm{BAX} = \mathrm{X}$. Students will deduce that the matrix B satisfies $\mathrm{BA} = \mathrm{I}_2$, which will allow us to define the notion of the inverse matrix. Now the question arises about the existence of such a matrix:

Let be $\mathrm{B} = \begin{pmatrix} 2 & -1 \\ -1 & 1 \end{pmatrix}$, demonstrate that $\mathrm{BA} = \mathrm{I}_2$. Then verify that the matrix B enables to reconstitute the original message. Student may think that in this case such a matrix does exist. Some of them may be wondering: If we don't give the inverse matrix of A then how we can compute the inverse matrix? This question may open up a window for a new point in the course: How to calculate the inverse of an invertible matrix?

5.3 Google and matrices' diagonalization

In the second year of the common core of lessons of engineers' level, our students will have to face the study of linear algebra especially the chapter «Endomorphism's Reduction ». This chapter provides a theoretical content, which demotivates students due to their interest to the new technologies. We therefore thought to change the classical presentation of the course without removing its core content. We then shifted to problematized course through the use of concrete examples, below some practical examples in relation with the chapter.

We introduce the algorithm PageRank, which computes a popularity index, associated with each Google's web page. This is the index that is used to sort the result of a search of keywords. The index is defined as follows" The larger the number of popular pages that link to it, the greater the popularity of a PageRank is". This definition is self-referential since in order to know the index of a page; we have first to know the index of pages, which have a link to this page. However, there is a very simple way to approach the digital value of the index. Each page is a graph node; each link with page is an arc between two nodes "Figure2" described in the figure below:

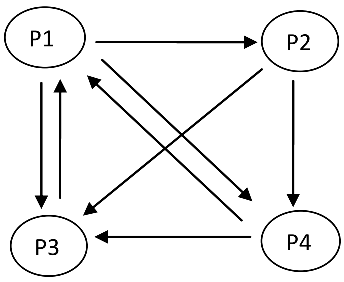

Figure2: Web pages and their connections

Google designers choose $\mathrm{x}_1, \mathrm{x}_2, \mathrm{x}_3, \mathrm{x}_4$ as popularity indexes referring to pages $\mathrm{P1}, \mathrm{P2}, \mathrm{P3}, \mathrm{P4}$. Students will have to describe the phenomenon through a system of matrices

$$\begin{pmatrix} 0 & 0 & 1 & 1/2 \\ 1/3 & 0 & 0 & 0 \\ 1/3 & 1/2 & 0 & 1/2 \\ 1/3 & 1/2 & 0 & 0 \end{pmatrix} . \begin{pmatrix} \mathrm{x}_1 \\ \mathrm{x}_2 \\ \mathrm{x}_3 \\ \mathrm{x}_4 \end{pmatrix} = \begin{pmatrix} \mathrm{x}_1 \\ \mathrm{x}_2 \\ \mathrm{x}_3 \\ \mathrm{x}_4 \end{pmatrix}$$

$$\mathrm{A}_\mathrm{G}.\mathrm{X} = 1.\mathrm{X}$$

We thus introduce the notion of eigenvectors and associated eigenvalues, as it is the case in a classical course except the student is able to better assess the utility of the newly acquired material. In order to demonstrate the utility of this example, we return to Page Rank to explain that the probability of the presence of a user on all the nodes of our graph Ag is represented by vector X.

Saying that the user is on page four of graph A_G is expressed below:

$\mathrm{X} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ is thus the following product gives the probability of occurrence of each of the four pages.

$$\begin{pmatrix} 0 & 0 & 1 & 1/2 \\ 1/3 & 0 & 0 & 0 \\ 1/3 & 1/2 & 0 & 1/2 \\ 1/3 & 1/2 & 0 & 0 \end{pmatrix} . \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} = \begin{pmatrix} . \\ . \\ . \\ . \end{pmatrix}$$

$$\mathrm{A_G} \quad . \quad \mathrm{X} \quad = \quad \mathrm{X}'$$

The student will understand that after n click, he will have to calculate $\mathrm{A_G}^{\mathrm{n}}$ to calculate the probability of presence of the user.

How to calculate $\mathrm{A_G}^{\mathrm{n}}$?

Then comes the description of endomorphism’s diagonalization via simple and classical examples that will remarkably grab your students’ attention.

6 Results

As any pedagogical method, our method presents positive points and negative points that we will be analyzed in what follows:

6.1 Advantages

Our experience has shown the appreciation of our students regarding the team-learning approach. In order to ensure the choice of the methodology, we have carried out a comparative statistical study based on the classroom assessment averages before and after the implementation of the new teaching method.

More accurately, we made the comparison on the same number of students, following the same study level with the same tutors and the same content. We have noted a significant increase in the exam scores and a lot fewer of students failed the first session (with mathematics credit).

We decided not to content ourselves with such proofs since we have also carried testimonies of students with a predominately positive response. Results indicate (Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P, 2014) that nearly all future engineers really appreciate that kind of activity. They consider that the regular work constraint is especially beneficial .Better understanding of the progress they may make and the difficulties that may encounter are highly motivating.

Experience has demonstrated that team based learning has highly contributed to the improvement of the pace of work that has become more regular and is no longer concentrated on exams period.

The tutor dominates the progress of the course works as it is the case with the traditional method but is more able to better assess the difficulties encountered by students.

The individual work is thus well framed and avoids students’ ideas to go in all directions. The acquisition and the memorization are significantly better with team based learning courses than with classical courses.

Certainly, this measure has contributed to the improvement of the engineering student interest to mathematics courses; however it still represents difficulties to deal with.

6.2 Drawbacks

First, the implementation of the new pedagogical device requires a change in habits as well as mentalities, which will not be easy to do.

The main tutors have shown their interest but still have difficulties to take the step and are afraid of failure. The shift from the classical teaching method to the active teaching method is very time-consuming and requires many efforts to draft the course in team based learning, look for the adequate problem and adjust them to the students' levels and learning objectives. This requires a specific training of trainers to the new methodology. Team working between tutors is thus necessary to relieve the burden of work with the distribution of tasks and for rich and fruitful exchange of ideas as well as the problematization of course.

Another point to be raised is the assessment means that remain traditional in terms of form and content. This seems incompatible with the used method, which requires a regular evaluation of the group and the individual for each of its member in order to identify the acquisition of skills and make sure the objectives are reached.

While we continue to give practical and concrete problems in the training, we still continue to evaluate through classical exams.

It is thus advisable to think of a new mode of evaluation in compliance with the active pedagogy approach.

To conclude, we are in a dynamic of exchange and reflection that suggest a construction of common interdisciplinary projects integrating mathematics (C . Rabut) That in turn requires working meetings between teams in projects in order to define the other subjects' needs in mathematics knowledge.

7 Conclusion

The used learning method should focus on the useful and necessary points for engineers' mathematics courses, on the one side, it will meet the teaching subjects' needs and on the other side, it will get them acquainted for the practical problems of professional life. An assessment will be presented to determine the challenges in successfully carrying out this innovation as well as its advantages. However, several improvements of the method are to be envisaged for the future and will be adaptable to all forms of theoretical courses.

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Project-Based Learning: Analysis after Two Years of its Implementation in the Industrial Engineering Course

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Abstract

This paper analyzes the use of Project-Based Learning in groups of new students in the Industrial Engineering at the School of Engineering of Lorena, at the University of São Paulo, in their first semester in the years 2013 and 2014. The students formed groups and each group had a tutor. In these two years, the main research instruments used were: 1) two questionnaires answered by the students, one in the middle of the semester and another at the end and 2) interviews with tutors. In addition, the material produced by the students of each one of the groups in these two years: reports, the minutes of the meetings and blogs was analyzed. The year 2013, the first year of application, was also a year of learning for the coordination and the results obtained allowed improvements to be made in the following year. The most important change was that the engineering project in 2014 required the delivery of a tangible product, in this case, a prototype producing biofuel, as in 2013, the final result was a conceptual project on sustainability at a University campus. In general, the main results, over this last two years were that: (i) - the use of Project-Based Learning was recognized by students as one of the greatest differentials in their course; (ii) - there was an acceleration in the development of transversal competencies of students, among which stood out: teamwork, project management and communication and (iii) - among these competencies, teamwork was one which had a biggest positive difference from 2013 to 2014, probably due to the intensity of the experimental work that occurred in 2014 when compared to the previous year.

Keywords: Project-Based Learning; Industrial Engineering; Freshmen.

1 Introduction

Engineering has as one of its fundamental pillars the design, planning, implementation, execution and evaluation of projects. Depending on the project relevance in the life of a professional engineer, project learning should be one of the central foundations of engineering courses. Many higher education courses, particularly those based in industrial engineering, have the project management discipline in their curricula, with greater focus on robust models of project management, among which PMBOK stands out in Brazil (PMBOK, 2013). But usually these are theoretical courses in which students learn the fundamental concepts of project management and PMBOK. In these cases, the student understands the main concepts of PMBOK and analyze, theoretically, the successes and failures of great projects already made, but usually has no "hands on" experience. However, effective learning about project goes beyond the simple acquisition of theoretical knowledge. It requires trial by the learner.

Active learning methodologies have increasingly being adopted in engineering courses over the past few years. UNESCO (2010) showed a consistent study on the graduation courses in engineering, which emphasizes the importance that engineering curricula to be based on relevant activities for students, among which stands out teaching activities based on projects and problems, and others . Due to this, over the past few years, there has been an increase on the usage of methodologies for active learning by universities. In line with UNESCO (2010), some strategies stand out, among which it is important to cite Project-Based Learning (PBL). PBL has as one of its main features the learning focused on student, using real projects as baseline for their learning.

PBL, unlike conventional educational methods, often leads students to execute projects without the corresponding theory presented previously. They are usually open solution projects aimed at stimulating the search for knowledge necessary for their solution, in a participatory and creative manner. The learning environment is very different from the traditional model of education, in which, still present in many engineering courses, having the instructor acting as an active agent of knowledge and the student, as a passive agent. In this new learning environment, the instructor roles as a mentor for the students to develop skills valued by the labor market, relevant in their professional lives, as there are many studies that show the incompatibility of graduates profile with the desired profile for future employers (Jackson, 2012).

In this context, PBL stands as a strategy for employability (Kolmos & Holgaard, 2010), to the extent that its features allow students to interact with real problems, which will allow them, among other skills, to develop entrepreneurial attitudes and innovation. In short, active learning methodologies, such as PBL, make the teaching/learning more meaningful and motivating for both students and for instructors. Studies in US schools, where there is an integrated curriculum for the first year of engineering courses, show an increase in student motivation, as well as a decrease in failures (Froyd & Ohland, 2005).

PBL was implemented in the course of Industrial Engineering at School of Engineering of Lorena at the University of São Paulo, Brazil, in 2013. Due to the good results obtained, it was used again in 2014. This study examines the use of PBL in groups of freshman students in the School of Industrial Engineering of Lorena Engineering, University of São Paulo, in their first semester in the years of 2013 and 2014.

2 Project-Based Learning (PBL)

PBL is a teaching and learning method that aims to develop and stimulate critical thinking of students and enhance their problem-solving skills through the usage of real world problems. One of the first definitions in the literature for PBL was performed by Adderley et al. (1975). For them, PBL should: (1) involve the solution of a problem; (2) involve the initiative of the students; (3) lead generally in a final product; (4) involve long-term projects, and (5) lead instructors to engage on an advisory role in all stages of a project.

The search for the answer to the question: "What must a project have in order to be considered an example of PBL?" led Thomas (2000) to point to five key factors for PBL: (1) PBL projects are central, not peripheral to the curriculum; (2) PBL projects are focused on questions or problems that "drive" students to encounter (and struggle with) the central concepts and principles of the discipline; (3) Projects involve students in a constructive investigation; (4) Projects are student-driven to some degree Significant and (5) Projects are realistic, not school-like.

Helle, Tynjälä & Olkinuora (2006) sought to define PBL and to distinguish the most important teaching or psychological reasons of this methodology. The authors proposed a combination of factors to validate the use of PBL: (1) the construction of a specific and tangible device; (2) the control of the learning process of the students, since the student is the factor that shall take decisions on the pace of work and its sequence; (3) the contextualization of learning should be evident; (4) the use of various forms of representation, as in working life, the interdisciplinary knowledge is crucial, and (5) the existence of motivating features for students.

Surgenor and Firth (2006) proposed that the project activities in engineering courses not be just a work of synthesis of knowledge, performed at the end of the course as a graduation project, and to start to be developed throughout the curriculum by student teams in order to become the guiding principle in the formation of an engineer.

For Moropoulou et al. (2013), PBL is housed in a pedagogical context known as "hands on" and "learning by doing", where the starting point is a proposed project to be developed by the students, and the end result is expected as a product delivery. This product can be contextualized as various types, such as a model, a prototype, a simulation software, among others.

Helle, Tynjälä & Olkinuora (2006) and Jollands, Jolly & Molyneaux (2012), among other authors point out that the use of PBL in the engineering curriculum is considered a way to add value to the student learning, as well as being recognized as an effective way to prepare students for their professional lives.

3 Methodology

The research method was the case study (Voss, Frohlich & Tsikriktsis, 2002) which is a powerful method, since it allows exploratory studies in order to develop hypotheses and/or survey questions, or even the development of new theories, and the enhancement of the understanding of existing theories. This method of research presents inductive approach to the analysis of the obtained data to and descriptive presentation of results.

3.1 Case Study Delimitation

The survey was conducted with students enrolled in the course "Introduction to Industrial Engineering" in the major of Industrial Engineering at the School of Engineering of Lorena, at the University of São Paulo, in 2013 and 2014. In 2013, the class numbered 46 students, with 40 of them entering in 2013. In 2014, the class had 43 students, 40 of them entering in the year of 2014. The other students, not freshmen, who were in the classes, were veterans taking this course as optional for their major course.

In 2013, six teams were assembled and each had 6 or 7 freshmen. In 2014, eight teams were assembled and each had 5 or 6 freshmen. In both years, all teams had an instructor in the role of tutor, who had the responsibility to guide the group, but could not interfere with the decision taken by this. Also in both years, each group had a leader and a secretary. The leader had as its main responsibilities the team coordination, meetings scheduling, and the distribution of tasks. The secretary had the job of preparing the minutes of the meetings.

In both years, a Project Guide, prepared by the subject instructor and by the tutors, was delivered to all students in the first class of the course. This guide was the instrument which explained the main objectives to be pursued, throughout the semester, and it defined the responsibilities of students and tutors and had the technical and soft skills presented (Figure 1), which were expected to be developed throughout the semester.

Project Management	Team work	Personal development	Communication
Research skills Decision making Organizational skills Time management	Autonomy Initiative Responsibility Leadership Problem Solving Interpersonal relationship Conflict management	Creativity / Originality Critical thinking Self evaluation Self regulation	Written communication Oral communication

Figure 1: Desired skills

In both years, the theme proposed for the project was an open problem that had no single solution. In 2013, the theme was "Sustainable University Campus". In 2014, the theme was "Biofuel Production". At this point, it is important to note that there was a significant change from the delivery of the project was made by the students at the end of each year. In 2013, the first application of PBL, the project was delivered as a theoretical report, as in 2014, delivery was a theoretical report plus a tangible product, in this case, a prototype producing biofuel.

In both years, the main events during the semester had the same sequence and were as follows: (i) - in the first class, the students received the Project Guide with instructions on PBL; the groups were assembled and the choice of leader and the secretary was performed; (ii) – in the second class, each group made a preliminary presentation on the project theme; (iii) - in the fourth class (2013), and the fifth class (2014), each group made an initial evaluation of the method, via an open questionnaire. The answers of the 2014 class were written, an improvement compared to 2013, where the answers were only noted by the subject coordinator instructor during the interview; (iv) – in the sixth class, a librarian gave a lecture on how to carry out research in scientific databases; (v) - in the seventh class, students gave the Preliminary Report of the Project and answered for the first time the “PBL Assessment Questionnaire”; (vi) - the eighth class, students made the oral presentation of the Preliminary Draft; (vii) - the ninth class, each group made the change of leader and secretary; (viii) - the fourteenth class of the course, students answered the same questionnaire the seventh class and delivered the Project Final Report and (ix) - the fifteenth and last class, the students made oral defense of the Final Project .

The only significant change occurred from one year to another, was that in 2014, students had access to a chemistry lab from the third week of class for four hours a week throughout the semester. And in the last week of class, in addition to the oral defense of the Final Project, made in the laboratory, the demonstration of the prototype operating and producing biofuel.

3.2 Data Collection

Data were collected through two questionnaires at different times of the course, and through interviews with each of the tutors.

A closed questionnaire, named "PBL Assessment Questionnaire", was applied twice, on the seventh and on the fourteenth meetings, for each of the classes. However, this questionnaire was enhanced from 2013 to 2014. In 2013, the questionnaire consisted of 23 questions that were reasonably arranged in a sequence of common themes. An analysis of this questionnaire led to its improvement in 2014, when the questionnaire had 29 questions and each group of questions was related to a dimension of PBL application for research purposes. From the 23 original questions of the 2013 issue, 15 of them were kept in full in 2014, the other 8 were reformulated seeking greater clarity of goals and 6 new questions were introduced.

A semi-structured interview was performed separately with each of the tutors during the first semester of the two years, on their last month of tutoring, before the delivery of the final report by the students. This interview took place through an open questionnaire with questions aimed at assessing the PBL methodology itself, the positive and negative aspects of its application, the analysis of the tutor's role in the project and the prospects of the tutor on regards to project to be delivered by groups. In the year of 2013, the interview had only the main points noted by the interviewer. In the year 2014, the entire interview was recorded, and later transcribed in full for analysis.

Additional sources of information were also used, which are: the minutes of the meetings and each team blog, as well as the reports produced during the course, and the oral presentations of each team.

3.3 Data Analysis

Quantitative data were obtained from the "PBL Assessment Questionnaire", through basic calculations of descriptive statistics, such as simple arithmetic averages and weighted averages.

Qualitative data were obtained from interviews with tutors, as well as from other supporting tools to the project (blogs, the minutes of the meetings, and reports). All these data were transcribed, in a very detailed manner, to particular documents, which allowed a systemic view of the dynamics that occurred during the semester, from the perspective of students and tutors. Therefore, it was possible to evaluate the evolution of the project, to evaluate the integration of groups, to infer about the written communication skills, and also to note the use of the communication protocols of each group during the evolution of the project. Furthermore, these data were relevant for evaluations regarding the development of transversal skills in the students.

However, it is important to note that this study being done has punctual methodological limitations, especially those related to data collection. This method is made using interviews with the tutors involved, and also using questionnaires answered by the students who are part of the project. These questionnaires, for instance, were reformulated in order to be improved, using feedback from 2013 conclusions into the updated version of 2014. These limitations provide a decrease in accuracy on the data triangulation. The discussed limitations are statistical significant enough to validate the study, but the room for improvement in the quantification of the results is a further motivation for the future plans of this research. This is particularly due to the importance and relevance of the theme and to the good results obtained.

4 Results

4.1 PBL Application

The "PBL Assessment Questionnaire", answered by the students in the middle of the semester (week 7) and at the end (week 15), in the years of 2013 and 2014, allowed the analysis of PBL acceptability as a teaching and learning method. Table 1 shows the four questions asked and the total averages for each of the two times when the questionnaire was applied to the classes of 2013 and 2014. These results show, in general, the recognition of the importance of PBL, that have already been good in 2013, was slightly better in 2014, which is supposed to be in line with the lessons learned by the project coordination on their first year in 2013. The greatest highlight stands for the almost unanimous recognition by the students that PBL application has been a substantial difference of the course, since the average score given by the 2014 group was 4.88 out of a maximum of 5.0.

Table 1: PBL Evaluation

Assertive	2013		2014	
	Week 7	Week 15	Week 7	Week 15
The use of PBL in the course "Introduction to Production Engineering" has been one of the advantages of this course	4.51	4.71	4.88	4.88
I understand that PBL concepts should be used in more courses	4.15	4.18	4.25	4.38
The use of PBL methodology makes the learning more motivating	4.31	4.07	4.58	4.47
The PBL methodology enhances the development of interpersonal relationships	4.73	4.68	4.78	4.72

4.2 Project Management

The skills related to project management are: research ability, decision making, organizational skills, and time management. It was expected on regards project management that teams followed the schedule and the project purpose, that they also knew how to delimit the area of operation for each proposal, knew how to enrich the results from solid research on the subject and were able to close the project with a solution that is technically economically and environmentally feasible. The questionnaire applied to students in 2013 did not have any specific question about project management. The questionnaire in 2014 corrected this flaw and had three specific questions about this competence, as shown in Table 2.

Table 2: Evaluation of the 2014 class on Project Management

Assertive	Week 7	Week 15
My group has met all the deadlines	4.34	4.59
My group has managed time successfully, fulfilling the proposed timeline	3.92	4.24
The expertise to develop the project are being sought from different sources	4.70	4.80

The results of table 2 show that students knew how to manage well the project, taking into consideration that they are engineering freshmen, as well as that they had an evolution on regards to project management in the second half of the semester when compared to the first half of the semester. This development suggests greater involvement of students throughout the project execution. An important result that should be emphasized is the research ability, as the students researched various sources for the project development on the theme of the project (biofuel), without any lecture on the subject.

In the interview with the eight 2014 tutors, it was found that: (i) - the team had a good degree of organization (3 agreed in part, 4 agreed completely and 1 reported that it had not been possible to evaluate); (ii) - the team knew to manage appropriate time devoted to the project (3 agreed in part, 4 agreed completely and 1 reported that it had not been possible to evaluate), and (iii) - the team knew how to seek the expertise to develop the project in different sources (3 agreed partially and 5 agreed completely). When they were asked about their perception about the students' evolution for specific skills in Project Management, compared to other students in the school in the same situation, they highlighted that on average these students ended the first semester of college, with: (i) - a superior research ability (2 partially agreed, 6 agreed completely, and 1 reported that it had not been possible to evaluate); (ii) - with superior organizational skills (1 partially agreed, 6 totally agreed and 1 said it had not been possible to evaluate), and (iii) - a superior time management capacity (2 in partial agreement; 4 completely agreed, and 2 reported that had not been possible to evaluate).

4.3 Team Work

The skills related to teamwork which aimed be accelerated with the completion of the project were: autonomy, initiative, responsibility, leadership, problem solving, interpersonal relationships and conflict management. The analysis of the development of these skills was possible from the "PBL Assessment Questionnaire", answered by students at two different times, according to the results in Table 3.

Table 3: Evaluation of the 2013 and 2014 classes´ on Team work

Assertive	2013		2014	
	Week 7	Week 15	Week 7	Week 15
All members of the group have contributed much to the success of the work	3.78	2.64	4.18	3.85
All group members have participated in all meetings	3.22	1.93	3.50	3.00
The success of my group is function of union among its members	4.00	3.32	4.18	3.95

Table 3 results show that there was a very good improvement of the class of 2014 compared to 2013 class, especially regarding the contribution of all to the success of the project, as well as the participation of all in all meetings. There are two factors that may have contributed to this improvement: (i) – in the class of 2013, the six veteran students were distributed one in each group, while in the 2014 class, veterans students were split into two groups by themselves, and (ii) - the class of 2014 worked on developing an experimental prototype (Biofuel) which required a more intense interaction between the students throughout the semester than the class of 2013, who just delivered a theoretical work on sustainability on campus. On the other hand, both in 2013, as in 2014, there was a reduction in the perception of the factors involved with teamwork in the second half of the semester compared to the first half. It is suggested that this may have occurred in relation to the natural wear of the relationship between the participants of a team over time, but this is a factor that needs to be evaluated.

The eight tutors of the 2014 class when asked about their perception of growth of these students in specific work skills as a team, from the average of the other students in the school in the same situation, highlighted that on average these students ended the first half of college, with: (i) - greater autonomy (2 agreed partially, and 6 agreed completely) and (ii) - a greater degree of responsibility (2 in partial agreement; 5 agreed completely and 1 reported that it had not been possible to evaluate). On the other hand, when asked about a possible evolution in interpersonal relationships or in relation to the management of conflicts, most tutors (6 of them) reported that it had not been possible to be assessed. The fact that tutors have a clear perception of the degree of autonomy and responsibility, while not assessing interpersonal relationships and conflict management can be related to the fact that the first two are easier features to realize the individual level, while the last two, for an analysis purpose, would require greater interaction with the tutor group, which is not the purpose of the project. These are points to be better exploited in the future.

4.4 Personal development

The skills related to personal development are: creativity / originality, critical thinking, self-evaluation and self-regulation. The questionnaire applied to students in 2013 had no specific question on Personal Development. The questionnaire was enhanced in 2014 and two specific questions about this competence were introduced, as shown in Table 4.

Table 4 – Evaluation of the 2014 class on Personal development

Assertive	Week 7	Week 15
I feel that the project helps me to develop my creativity to solve problems	4.61	4.21
I find myself with a stronger critical sense that helps me to evaluate the different work proposals	4.38	4.15

The results in Table 4 show that students, in their own opinion, had the perception that factors related to personal development show a positive scenario, i.e. that they have evolved in relation to creativity and critical sense as a function of having worked in project. On the other hand, there was a reduction in the perception of these two factors in the second half of the studied semester when compared to the first half. This reduction may even mean that the critical sense of the students at the end of the semester could have been better evolved than at half of the semester, but this is just a hypothesis to be investigated in the future.

The interview with the eight tutors of the 2014 class found that over half the team proved to be very creative in their proposals (3 tutors partially agreed with this and 5 agreed completely). And when asked about their perception about the growth of these students in relation to creativity, compared to other students in the school in the same situation, highlighted that on average these students ended the first semester of college, with a development of greater creativity (3 in partial agreement 5 and agreed completely). Therefore, from the point of view of the tutors was noticeable that the use of PBL accelerates the development of creativity in students starting an engineering degree.

4.5 Communication

Oral and written communication skills were those related to communication aimed at being accelerated. Students during the execution of the project during the semester delivered reports and made presentations in which everyone should speak. The goal was for them to develop writing and oral communication skills, which was the subject of a specific question in the questionnaire introduced in 2014. When asked if "Have my skills in written and oral communication been challenged in this project?" the response obtained was 4.53 (on a scale from 1 to 5) on week 7 (half of the semester) and 4.41 on week 15 (end of the semester). Therefore, it was observed that in the opinion of the students, they had the clear perception that your communication skills had been challenged during the project, which results in an increase in written and oral communication.

Another factor related to the statement that was investigated in both years, and that was the subject of a quiz question in both years, was on the effectiveness of group communication through a protocol (8 groups embraced Facebook, 7 groups used together Whatsapp with Facebook, and 4 groups also communicated, besides these two means, by e-mail). The answer is in Table 5.

Table 5: Evaluation of the 2013 and 2014 classes´ on communication protocols

Assertive	2013		2014	
	Week 7	Week 15	Week 7	Week 15
The communication of the group through the communication protocol has been effective	4.45	4.21	4.45	4.16

The eight tutors of the 2014 class when asked about their perception about the growth of these students in the competence of communication in relation to other school freshman students in the same situation, highlighted that on average students who worked on the project evolved more (2 partially agreed, 4 agreed completely and 2 reported that it had not been possible to evaluate). As for the growth of these students, in relation to written communication, two tutors agreed partially, 4 agreed completely and 2 reported that it had not been possible to evaluate. On regards to the evolution of these students for oral communication, 3 tutors agreed completely and 5 reported that it had not been possible to assess. This last result is explained by the fact that tutors did not attend the oral presentations made by the students during the semester, but all attended the presentation in the last class of the semester, but the interview was conducted before this final presentation.

5 Conclusions

The application of PBL to a class of freshman students in Industrial Engineering at the School of Engineering of Lorena, at the University of São Paulo, in 2013 and 2014 was the scope of this work. This study provided an acceleration in the development of transversal skills in their learning activities when compared to the traditional methods of teaching that are adopted by most of engineering courses in Brazil.

To determine the advantages and disadvantages of the use of PBL methodology in 2013, in its first year of implementation, several research instruments were used. The analysis carried out with the 2013 results allowed the improvement of the instruments used and the introduction of new ones in 2014. This enabled a more consistent analysis of the implementation of PBL as a whole.

The main results obtained in these two years were: (i) - the application of PBL was recognized by the students as being one of the great differentials of their major; (ii) - the students have developed transversal competences, such as teamwork, project management, and communication on a higher rate than they would have developed using traditional methods of teaching, and (iii) - among these skills, development of teamwork was the competence in which there was the most significant change from the class of 2013 to the one of 2014.

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Teamwork: Analysis of This Competence over Two Years for Freshmen Industrial Engineering Course.

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Abstract

Teamwork is one of the most important competences in the life of any professional. For engineers, it is a core competency. Engineers will operate and manage teams along their career. The development of teamwork is one of the most expected benefits from the application of Project Based Learning (PBL). The freshmen in 2013 and 2014 in the course of Industrial Engineering at the School of Engineering of Lorena, at the University of São Paulo who enrolled in the subject "Introduction to Industrial Engineering" acted in projects through PBL methodology. In 2013, the first year of use of PBL application, one of the weakest points was the development of teamwork. In 2014, teamwork was one of the points in which the Coordination gave more focus. The goal of this study is to evaluate the development of teamwork over the two years in which PBL was used. A case study was conducted. The main research tool used was a closed questionnaire, which all students from 2013 and 2014 answered at two different moments: in the middle and at the end of each semester. The results showed that in 2014 there was a great evolution in the following points: 1) the contribution of all members of each group for the success of the project; 2) the participation of all group members in the meetings and 3) the perception that the success of the team was due to the union among its members. On the other hand, in both years, the perception of teamwork was lower at the end of the semester in relation to the middle.

Keywords: Project Based Learning; Teamwork; Teamwork Development.

1 Introduction

Companies have been searching for increasingly well-qualified professionals with solid technical knowledge in their fields as well as a series of soft skills such as analytical thinking, communication and teamwork, for example, which can assist to develop the company (Jackson, 2014).

This change in the business landscape has led to changes in higher education that now has not only the mission to teach the technical knowledge, but also to prepare students to work in teams, lead projects and manage time, for example. To achieve this, many universities have sought methodologies that take students out of the role of mere spectators and put them into the propagators of knowledge position. One of these methodologies is Project Based Learning (PBL) where, through projects, students should seek knowledge in various sources available to complete in a timely manner the proposed project. During the execution of this project, they have the opportunity to interact with the relevant situations to be faced in the future when venturing into the labor market. Among these situations, they are living and working with a team composed of many different parts. According to Roberts (2002), each member of a team has preferences and more developed skills for different tasks, allowing the construction of a complete team. In addition, there is also a common goal to the team, allowing greater involvement of the members in the project, reflecting the commitment that each one has with the final product to be delivered. (Male, 2010)

PBL was implemented in the School of Engineering of Lorena, University of Sao Paulo in 2013, in the course of Industrial Engineering in the discipline of "Introduction to Industrial Engineering" with the freshmen from that year, and continued in 2014. This work aims to analyze the evolution of the development of teamwork competence in the two years of use of PBL methodology.

2 Project Based Learning (PBL)

The project-based learning is a teaching-learning methodology that has existed since the 1960s, emerged in medical schools in order to prepare the students the best way possible. The application of this way of teaching in the education of future engineers is relatively new and also very little spread. It is used to assist in the education of students and meet certain easily identified needs, with main emphasis on the lack of preparation when the student moves from college to the labor market as a situation resulting from the little contact that students have to the practical part of their courses.

According to Mills and Treagust (2003), PBL is basically the identification of a problem or situation by the students for which they should propose solutions, as they themselves learn about the specific content required for the completion of the project. PBL is focused on the application of knowledge to real situations, varying the complexity of the project along the development of students, but always relating to theoretical disciplines that serve as the basis for project execution. During the period dedicated to finding relevant solutions to the problem/starting point, the groups themselves should care about time, task and conflict management in order to complete the proposed project, helping them to develop soft skills (teamwork, leadership, communication) that are constantly needed in the labor market and are often not found in engineers who just graduated. (Lu, 2007)

Also according to Mills and Treagust (2003), one of the most important points of the PBL is the absence of a single correct answer. The students themselves are free to take different paths to their proposals, they all work from the same common starting point, based on what they learned and what they believe to be most appropriate/viable. For Graff & Kolmos (2003), the project serves as a basis for the learning process in that it puts the focus on the question asked rather than in the response itself.

According to Savery (2006) it is important to note that the PBL methodology is student-centered learning, allowing, therefore, that these students participate in projects that challenge and stimulate their knowledge. Complementing this idea, to Graaff & Kolmos (2003), the teacher is replaced by the figure of a facilitator and the discipline itself becomes organized around the project to be executed, paired with the supporting disciplines.

3 Teamwork

For a long time interdisciplinarity has been a word associated with the profession of engineers to the field of exact sciences and with a strong focus on innovation. However, more and more it is demanded that engineers consider social and environmental impacts of their technologies during the decision making process, in addition to work in complex groups that require skills that allow the maximum interaction and cooperation among team members. (Barbour, 2006; UNESCO, 2010)

According to Marquez, Martinez, Romero & Perez (2011), the team work experience during college enables students to interact better with their teams when, in the future, they are in the job market. Engaging in this kind of activity during the university is important for students to develop work in complex environments requiring collaboration for the development of the project and members involved. (CTL, 2001; Savery, 2006)

According to Lees (2002), teamwork can also be seen as the solution of organizational problems because it allows the development of a sense of involvement and negotiation skills. However, there is a difference between the level of these skills required by companies and the level of the students right after finishing their courses, influencing the performance of students in the job market. (Stiwne & Jungert 2007)

Thus, it is necessary that current engineering courses provide experiences within the classroom that simulate a real team, allowing the development of soft skills and, among them, teamwork (Marquez, Martinez, Romero & Perez, 2011). So, PBL allows greater interaction not only among the students and the teacher, but also the opportunity to deal with students with different world views and experiences. (Vicente, Romano, Sá & Lima, 2014)

4 Methodology

This work was built as a case study that according to Voss, Tsikriktsis & Frohlich (2002) is one of the most suitable methods in cases of empirical and qualitative research, seeking the explanation of a phenomenon inserted in a real context.

4.1 Research Objective

The target in this case study is made up of 2013 and 2014 freshmen in the course of Industrial Engineering at School of Engineering of Lorena - University of Sao Paulo. The application of PBL was performed in the "Introduction to Industrial Engineering" course, taught in first semester of each year. The class of 2013 had 46 students, with 40 freshmen and 6 veterans, and was divided into 6 groups, each with 6 or 7 students. The class of 2014 was composed of 43 students, with 40 freshmen and 3 veterans and was divided into 8 groups of 5 or 6 students.

4.2 Data collection and analysis

Data collection is a fundamental part of the case study, therefore, from the different tools used for the collection that it is possible, through the triangulation process, check points of convergence or divergence.

Thus, it was used in both groups, a closed questionnaire with questions grouped into different skills sets to be analyzed, applied at two different times of the semester: in the seventh class of the course and at the fifteenth class of the course. This questionnaire, called "PBL Assessment Questionnaire", was answered individually, and had three claims related to the Team Work, on a scale from 1 to 5 where 1 means "Strongly Disagree" and 5 indicated "Strongly Agree".

The results obtained in applications of "PBL Assessment Questionnaire" for the 2013 and 2014 classes allowed analysis of the development of teamwork competence over the two years studied.

5 Results

Three questions relating to work in a team used the "PBL Assessment Questionnaire" are now analyzed. They are:

1 - All members of your group have contributed greatly to the success of the work.

2 - All members of the group have participated in all meetings.

3 - The success of my group is the result of the union among its members.

Tables 1 through 9 show the result for each group of classes 2013 and 2014 for each of the three statements (Results of assertive 1 - Tables 1 to 3; results of assertive 2 - Tables 4 to 6; results of assertive 3 - Tables 7 to 9). In all these tables, the notation used is as follows: the six teams of 2013 are represented as 13-A, 13-B through 13-F. The same reasoning is done for each of the teams of the 2014 class, going 14-A, 14-B to 14-H.
Tables 1, 2 and 3 present the results for the first statement: **All members of the group have contributed greatly to the success of the work.**

Table 1: Results of statement 1 – Class of 2013

13-A		13-B		13-C		13-D		13-E		13-F	
7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th
3.86	3.00	2.63	1.50	3.00	2.20	3.14	1.75	4.50	4.33	3.50	4.00

Table 2: Results of statement 1 – Class of 2014

14-A		14-B		14-C		14-D		14-E		14-F		14-G		14-H	
7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th
3.25	4.20	5.00	2.67	4.50	3.33	4.17	4.83	4.25	3.80	4.20	4.00	3.00	4.00	4.17	4.20

The results of Tables 1 and 2 show that in the class of 2013 was increased mean of two groups (A and F) in the second questionnaire, while the average for the other four groups (B, C, D and E) decreased. Already in 2014, you can see that four groups (A, D, G and H) had higher averages in the second application in relation to the first, while other four groups (B, C, E and F) showed a decrease of the average. It's possible to see that from 2013 to 2014 there was a significant increase in the average found for the analyzed statement, suggesting that students of class of 2014 were generally more committed to the project than students of class of 2013. It is also possible to see that in 2014 the group B presented an average of 5 to claim 1, that is, all students in the group agreed completely with the statement that all members were contributing to the satisfaction of the completion of the project, a result that was not found at any time in 2013. However, continuing the analysis, one can see that this same group showed a marked fall of the seventh to the fifteenth class, being the only group to suffer such a severe drop in two years. This indicates that this particular group must have had at least one member that was little involved in team work during the second half of the semester.
Table 3 shows the total average of all students to the classes of 2013 and 2014.

Table 3: Total results of claim 1 for the classes 2013 and 2014

13-Total		14-Total	
7th	15th	7th	15th
3.78	**2.64**	4.18	3.85

From Table 3, it becomes clear the increase in average from 2013 to 2014. In the first application of the questionnaire in both groups (seventh class), we can see that the contribution of all members of each group was considered important for the work success. In the second application of the questionnaire (fifteenth class), there is a more significant difference, since the Class of 2013 has a very large reduction, resulting in the recognition that not all students contribute to the success of the project, while for the Class of 2014, members of each group satisfactorily contributed to the success of the work, even if there was a decrease in the average of this statement. The result for 2014 indicates that there has been significant progress on the issue discussed here, since the lowest average found in the fifteenth class, exceeds the highest average 2013, found in the seventh class

Statement 2: **"All members of the group have participated in all meetings**" have their results presented in Tables 4-6.

Table 4: Results of statement 2 – Class of 2013

13-A		13-B		13-C		13-D		13-E		13-F	
7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th
3.71	1.67	2.50	1.33	1.33	1.40	2.29	2.00	4.00	3.33	2.83	2.75

Table 5: Results of statement 2 – Class of 2014

14-A		14-B		14-C		14-D		14-E		14-F		14-G		14-H	
7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th
3.50	3.80	4.40	2.67	4.67	3.00	4.00	3.17	3.50	3.00	2.60	3.00	3.00	3.33	2.00	2.20

Tables 4 and 5 allow us to observe that in 2013, only one of the groups (C) showed an increase in the average, but marginal. The other groups had more significant decreases, with groups A and B showing the largest declines. Already in 2014, four groups (A, F, G and H) presented additions to the first application values, more significant than the increase seen in the previous year. As for the other four groups (B, C, D and E), it's possible to see a decrease on groups' average, highlighting again the results of group B, with the highest fall of 2014, which reinforces the explanation for the results of claim 1, that at least one member of the crew must have gone in the second half of the semester. The results presented also indicate that at no time groups of two years were able to gather all the members at the meetings they were doing. But it is remarkable that for the 2014 groups, there was more student's participation in the meetings. Table 6 summarizes the average results of two years.

Table 6: Total results of statement 2 for the classes of 2013 and 2014

13-Total		14-Total	
7th	15th	7th	15th
3.22	**1.93**	3.50	3.00

From the results of Table 6, it is noticeable that in 2014 there was a greater participation of members of the groups in meetings that were made. It is also notable that the maintenance of student attendance at meetings was much more satisfactory in 2014, as the decrease in the overall average was lower than the 2013 by placing the lower value of 2014 (fifteenth class) very close to the results found for both years in the seventh class. This result suggests a lack of motivation among students with work, failing to attend the meetings. But from 2013 to 2014, it is possible to see that this evasion of the meetings was lower, which may be related with the main goal in the 2014 class, which involved the construction of a prototype.

The statement 3: **"The success of my group is the result of the union between its members"** have their results presented in Tables 7-9.

Table 7: Results of statement 3 – Class of 2013

13-A		13-B		13-C		13-D		13-E		13-F	
7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th
3.57	3.50	4.13	3.50	3.83	2.40	3.14	3.25	4.33	2.67	3.83	4.50

Table 8: Results of statement 3 – Class of 2014

14-A		14-B		14-C		14-D		14-E		14-F		14-G		14-H	
7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th	7th	15th
4.00	4.20	4.40	3.50	4.33	3.33	4.42	4.83	4.50	4.80	4.60	4.40	3.50	3.33	3.00	3.00

Analysis of the 2013 class (Table 7) shows that only two groups (D and F) showed an increase in its results from the seventh to the fifteenth class, while the other four groups had higher (groups C and E) or smaller (groups A and B) decreases. The Class of 2014 (Table 8), on the other hand, shows that again only two groups (A and E) showed an increase in its results as a group (H) remained unchanged with the result and the other five groups (B , C, D, F and G) showed decreases, though none has been as sharp as those found in 2013.

Table 9 brings the overall results for the claim 3:

Table 9: Total results of statement 3 for classes 2013 and 2014

13-Total		14-Total	
7th	15th	7th	15th
4.00	**3.32**	4.18	3.95

The overall results allows us to view the students' perception of the two years that the union of the members led to the success of the group are not that different, although there is an increase from 2013 to 2014. Here, more striking is the comparison between the two applications each year, since the decay in 2013 is much more pronounced than in 2014. One possible explanation for this change may be that students of the 2014 class depended on the team as the design theme required more mastery on specific concepts, making the students more united in the construction of knowledge. The results in this statement match to the results of the first statement analyzed (All members of your group have contributed greatly to the success of the work), since the analysis of the first statement seems to point to a greater commitment of the members of the Class of 2014 groups in general, which may have led to greater unity among the members, who were already involved with the work.

The results in these three statements suggest that some changes made from 2013 to 2014, such as choosing a theme that required practical work and expertise, in addition to constant stimulation made by the discipline professor for groups to work together on tasks not only related to the project, but also related to other topics, led to an increase in all analyzed overall averages. This increase indicates that, for some reason, there was greater interaction of all students in groups, contributing to the completion of the project. One of the reasons that can explain this difference in the grades is the theme of each project. While in 2013, the project was about sustainability on a university campus, with the ultimate goal being a theoretical report on the topic, in 2014 the project was the production of biofuel, requiring groups to submit a working prototype, and the creation this prototype required from the groups not only theoretical knowledge but also experimental work in laboratories and field research, which led students to know even more the academic community to which they belong. It is also possible to note that there is decay of the grades from the first application of the questionnaire (seventh lesson) to the second (fifteenth class) in both years, although in 2014 this decrease was lower. This situation in the second half of the semester can be explained from natural wear of the relationship between people in the case, students, over time. It is possible that the greater proximity of the group members for the needs of trials has helped more Class of 2014 in the maintenance of groups union during the semester than the Class of 2013 with the theoretical design. Only further research in the following years will analyze these results better.

6 Conclusion

The results reveal, in general, that use of the PBL methodology for freshmen to the course of Industrial Engineering contributes with the development of teamwork skills in the students. Furthermore, it was possible to verify that Class of 2014 had a great evolution compared with Class of 2013 in the following aspects: 1) the contribution of all members of each group for the success of the project; 2) the participation of all group members in the meetings and 3) the perception that the success of the team was due to the union among its members.

On the other hand, in both years, the perception about teamwork was lower at the end of the semester than in the middle of the semester, which suggests a natural wear of the relationship between group members. However, in the Class of 2014, there was greater cooperation, once the project in this year required a more active participation from the students, also involving experimental and more tangible parts than a theoretical paper.

One can also conclude that efforts made by the discipline coordinators were effective for the 2014 students to work better in groups, according to the comparison of results obtained during the two years of the use of PBL in the discipline.

Finally, you can see that it takes more effort for the development of teamwork competence to be improved every year in the discipline, with more engaging topics, containing practical parts and to enable the maximum contact between the group members.

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Development the Competence of Project Management for Freshmen in Industrial Engineering Course

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Abstract

The Project Based Learning (PBL) aims to carry out projects that bring an engineering student close to his real life of engineer in the future. These projects, in the context of PBL, have as their main characteristics: (1) involve the solution of a real problem resulting in a tangible final product; (2) take a few months to be conduct and (3) make the student the active agent of his own learning. One of the most valuable competences expected from a good engineering professional is that he knows how to operate and manage a project team. The PBL was applied to freshmen in Industrial Engineering at the School of Engineering of Lorena, at the University of São Paulo, in the semester of 2014. Students enrolled in the subject "Introduction to Industrial Engineering" were divided into eight groups to develop projects on the theme: biofuel. Each one of the teams had a tutor as a counsellor. A case study was conducted and data were collected through questionnaires applied to tutors and students. The goal of this study is to analyze the development of competence of project management. For the purposes of this analysis that competence (Project Management) was split into four main elements: 1) research capacity; 2) Ability to make decision; 3) organization and 4) Time management. It was found through the questionnaires, that students: 1) had their research capacity improved, as they sought the expertise to develop the project from different sources; 2) made their own decisions during the execution of the project; 3) showed a reasonable degree of organization, but had some difficulty to define the roles of each one on their teams clearly and 4) were able to manage time, as they kept all deadlines. In short, the use of PBL proved to be very effective for the development of key elements that make up the competence of Project Management.

Keywords: Project Based Learning; Project Management; Engineering.

1 Introduction

Technological advances marked a new era in society. Combined with social and environmental change, technology has changed the way people communicate and how the information is transmitted, determining a new era in interpersonal relationships. Because of it, the market for engineering has increased the need for professionals with "non-technical" skills, in addition to the minimum technical skills expected of a good undergraduate degree.

Skills that are considered "non-technical", known as "soft skills", have become fundamental in the work environment. In the present scenario, the qualified professional must have soft skills in addition to technical qualification. In traditional education, expertise of an engineer are highly developed while non-technical skills are little worked (PRINCE, 2006). This makes the newly graduated engineer from the labor market without being fully qualified for the daily challenges and should, therefore, get qualified when it is already working. Because of this, the institutions must better prepare students, so they are able to perform these duties at work (JOLLAND & JOLLY & MONLYNEAUX, 2012).

Preparing the student for the labor market, has become a challenge for the engineering colleges. Most engineering schools offers students courses with curriculum and traditional teaching method, based on transmitting education teacher for students while few schools use project-based methods, in which the student is the center of their learning and the professor is the advisor (THOMAS, 2000).

Project-Based Learning is characterized by providing the engineering student an experience close to the reality found in their future professional life. The main objective of this work is to analyze the development of the Project Management competence in a freshman class of a production engineering course.

2 Project Based Learning

The traditional model of education, focused on the teacher, where the student is the learning liabilities subject, has little effectiveness in question retention of knowledge. Among the ways that students retain knowledge, only 5% of retained knowledge is due to the traditional classes, while 75% is "practice doing it", that way, put into practice the knowledge acquired. This is represented in the learning pyramid cited by Singhal et al (1997) and Surgenor and Firth (2006).

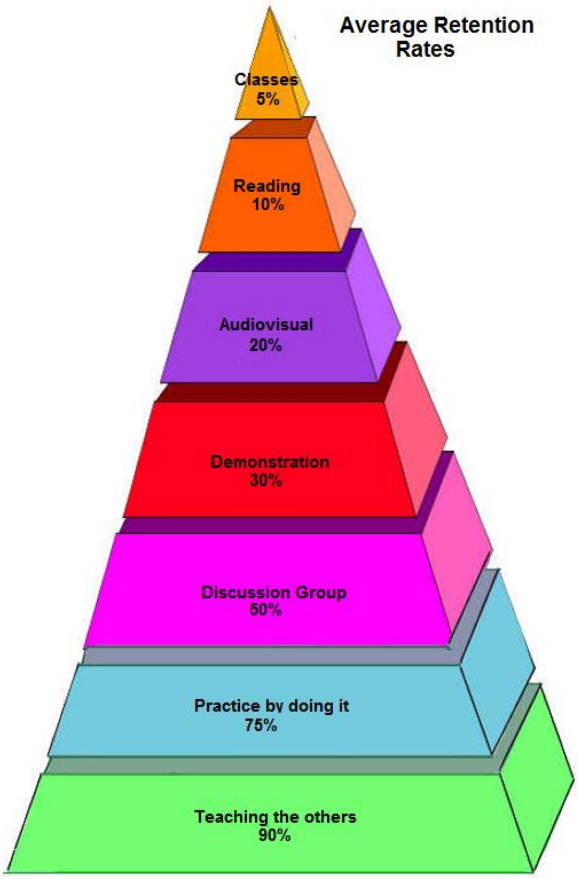

Figure 1: Learning pyramid. Source: Singhal et al (1997) e Surgenor e Firth (2006)

The active methods are responsible for putting the student at the center of learning, making it an active part in teaching. This makes it the education most dynamic and provides students greater autonomy and exposure to knowledge retention.

One of the best ways for students to learn is by doing experiments and/or putting the technical and theoretical knowledge into practice. Among the methodologies based on projects, consisting of a teaching model based on delivering projects, the PBL stand out. This methodology is characterized by placing the student at the center of the learning process; they are responsible for building their own knowledge, while the teacher has the role of advisor or learning facilitator.

PBL is characterized by participant-directed learning processes, that is, knowledge directed by the student, the student defines the problem and working methods (Graff & Kolmos, 2003). The methodology approaches the professional reality, placing the student in very similar situations experienced in real jobs. That makes this method consisted in the application of theoretical knowledge of any material, featuring interdisciplinarity (Mills, 2003). This way, the student join the labor market better prepared to face the daily challenges, knowing troubleshoot high degree of complexity problems.

3 Project Management

According to Kerzner (2006), project is an achievement with deadlines and defined objectives that demand resources to meet a qualitative result. This way, project management is related to planning, programming and control tasks with defined objectives, aiming to fulfill them in favor of those involved.

The realization of a project can be divided into four steps that overlaps itselves and are interactive: planning, design, implementation and deactivation (KERZNER, 2001). In the planning phase, the objectives, goals, the problem situation, schedule and resources are defined. The drafting phase, develops the plan for the project completion, determining the staff and the methods to be used. In implementation phase, everything is revised and if it is as planned, the evolution of the process is managed and the schedule goes on. On deactivation, a final evaluation of the project and participants is made.

According to Meredith (2011), the implementation of projects is bound to uncertainties and risks. The risks that the project is bound to should be taken in stock, this way a plan can be created to prevent and / or minimize its consequences and impacts. Project management is made from the use of different capabilities, such as: research capacity, organizational skills, decision making and time management

Risk management is directly related to decision-making capacity. During the project unforeseen and unplanned events arise, so those involved in the project must be qualified to solve the problem without affecting the schedule and the quality of the final project.

While the organizational skills is related to the planning and the group organization throughout the completion of the project, research capacity is related to the ability of members to seek knowledge from different sources.

Time management is related to compliance with the schedule that means, it is related to the group's ability to turn in assignments within the stipulated time, in addition to the project completion by the deadline.

4 Methodology

This paper uses the method of case study research because it is a qualitative study thus allowing the analysis of the collected data. According to Voss, Tsikriktsis & Frohlich (2002), the case study is one of the most effective methods for having empirical research of a particular phenomenon within a real context. This qualitative methodology allows to investigate, analyze, describe and explore the phenomenon to create a conclusion to this.

It is important to perform a case study that researchers use different sources of data, such as questionnaires, interviews, letters, documents, and others that allow the crossing of the collected data. The case study facilitates searching for answers in addition to the description and analysis when phenomena are complex situations (Yin, 2001).

4.1 Research Universe

The research was conducted with 43 students of the first year of Industrial Engineering, freshman in 2014, in the School of Engineering of Lorena, University of São Paulo, in the discipline of "Introduction to Industrial Engineering". Of these 43 students, 40 of them were freshmen and three were veterans taking this discipline as an optional.

In the discipline "Introduction to Industrial Engineering", students had the challenge of performing the design of a prototype that would produce biofuel. Students were divided into 8 groups of 5 or 6 members, and the members of the group were randomly chosen. Throughout the semester, students had available a chemical laboratory equipped with the necessary materials to perform experiments, as well as a technician for security reasons. Each group had a teacher tutor to assist in the realization of the project, who are teachers of School of Engineering of Lorena, and a sponsor, who was a senior student of the second or third year of Industrial Engineering.

At the end of the semester, the groups prepared two presentations: an experimental and other theoretical. Experimental should show the operation of biofuel prototype, while the theoretical should make an explanation of the prototype built and how the project was carried out. In addition to the presentations were delivered two reports: a preliminary, in the middle of the semester, and the other end.

A Project Guide, prepared by the professor with tutors, was distributed to all students in the first class of the course. This guide detailing the main objectives to be achieved at the end of the project and presented the technical and soft skills expected to develop throughout the semester. Competence Project Management unfolded in four key factors: research capacity, capacity of decision, organizational capacity and time management.

4.2 Data Collection

Data were collected from questionnaires applied, with students and tutors, besides delivered reports analysis, observation of the presentations and monitoring of groups in social networks. Four questionnaires were applied at different times, throughout the semester, one for tutors and three for students.

The same questionnaire containing 29 closed questions was applied twice, once in the middle of the semester (class 7) and another at the end of the semester (Class 15). Students had the option of answers an interval scale of one to five, and the answer to "strongly disagree" was assigned a degree 1 and the "strongly agree" was assigned a grade 5. These questionnaires were intended to get feedback on relationship: (i) the methodology used, and (ii) the following soft skills: teamwork, project management, communication and personal development, among other aspects. For purposes of this article are analyzed 6 of 29 questions, because those are the questions that are related to project management.

Another questionnaire, this time with open questions was answered by students in the sixth class of the course, in order to assess the progress of the project.

For tutors, the questionnaire had four response options (strongly disagree, disagree partially, partially agree and strongly agree), but with an additional option for the answer: "unable to assess". The objective was to assess the teacher's view of the soft skills that students develop.

4.3 Data Analysis

The data analysis was done by analyzing the questionnaires, presentations and reports submitted by students. The analysis of the results is made for each of the four key factors that make up the project management competence: research capacity, organizational capacity, decision-making ability and time management. These four factors gave direction to the presentations and reports were analyzed in order to identify and analyze all the information they were related to the factors

5 Results

The study of Project Management competence was carried out from each of the four key factors that composed it: research capacity, organizational capability, decision-making capability and time management. The closed questionnaire applied to students at two different times (seventh and fifteenth class of course) had six questions related to Project Management. The answers to these questions are shown in Tables 1, 2, 3, 4; where the first column represents the assertion presented to students, while the second and third column refer to the arithmetic mean of the answers given by the students in the classes in which the questionnaires were applied (class 7 and class 15).

5.1 Research Capability

The research capacity of the students was assessed by means of a question asked directly to them and through another made to tutors.

Table 1: Question related to research capability, questionnaire applied to students

Assertive	Class 7	Class 15
The expertise to develop the project are being sought from different sources	**4.70**	**4.80**

The data presented in Table 1 show that the students used different data sources for the formation of a theorical basis for the conduct of their work and the construction of the prototype. It is important to highlight that were new students who received the challenge of building the prototype in their first semester of the undergraduate program. The small increase in average after applying the second questionnaire may be related to an increase in search of a theorical framework to carry out the work in the second half of the semester for the first half, although the difference is statistically very small.

The question asked to tutors related to research capability of students (students were able to seek expertise develop the project from different sources) was answered that students have sought knowledge from different sources (5 answers "strongly agree" and 3 "partially agree ").

Therefore, the responses of students and teachers shows that students performed well as the search for knowledge, revealing that the research capacity related to the project was well developed.

5.2 Decision-Making Capability

The decision-making capability was assessed by means of a question asked to students and other for tutors, plus the open questionnaire with students.

Table 2 – Question related to decision-making ability, questionnaire applied to students

Assertive	Class 7	Class 15
The meetings have been productive and decisive for the continuation of the project	**4.42**	**4.00**

Data presented in table 2 show that the students assessed the meetings have lost efficiency in the second half of the semester compared to the first half. This may be because some groups have managed to achieve the objective of the project before de deadline, and other groups are very well underway with the project. Something that reinforces this possibility is the fact that one of the questions of the open questionnaire with students in the sixth class, was: "The meetings have been productive? If yes, how "One of the groups replied: " Yes, because the group has managed to achieve the main objective of the project: to produce the chosen biofuel".

The tutors, when asked about the growing autonomy of the students in relation to other new students in school, have stated positively to the fact that new students in Industrial Engineering developed greater autonomy in relation to others (6 answers "strongly agree" and 2 "partially agree").

Therefore, according to the responses of students and teachers, the decision-making capability was favored due to achievement of the project, with only a decrease in the decision-making capacity in the second half of the semester, suggesting further research in the future to better assess which may have occurred.

5.3 Organizational Capability

Organizational capability was assessed by means of two questions asked to students and others two to tutors.

The answer of the first question apparently refers to a direct failure of the secretaries of the groups in the preparation of the minutes after the meetings and / or in disclosure to all teammates. However, the second question answer reveals that the groups agree that lack a definition of the functions of each, but at a low level, in the range from 3.0 to 4.0 points. This rather, is an important feature that suggests a better analyze by the project's coordinating teachers in the future, given the importance of this point for the workplace. Finally, it should be mentioned also that both issues reveal a reduction in the assessment of students in the first half of the semester for the second half.

Table 3: Questions related to organizational capability, questionnaire applied to students

Assertive	Class 7	Class 15
The secretary has made the minutes of all meetings and divulged to all members of the group.	**4.11**	**3.58**
the functions are well defined and all have been working in their proper functions.	**3.95**	**3.56**

On the other hand, tutors assessed as good the organizational capacity of the students, because when asked about the students have a good degree of organization, tutors answered "strongly agree" (4 answers), "partially agree" (3 answers) and "unable to assess" (1 answer). Another question that has been formulated to tutors, was on their perception towards the students have developed more organizational capacity than the other freshmen students who did not use PBL, six tutors agreed fully while a partially agreed and one did not know assess.

5.4 Time Management

Time management was assessed by means of two questions asked to students and others two to tutors.

Table 4 – Questions related to time management, questionnaire applied to students.

Assertive	Class 7	Class 15
My group has complied with all the deadlines.	**4.34**	**4.59**
My group is managing well time, fulfilling the proposed timetable.	**3.92**	**4.24**

Table 4 shows a good time management by the students as well as the improvement in the assessment of this factor during the semester, because the groups had a good average, demonstrating knowledge how to deal with the issue of deadlines. An important point to note is that all deadlines for delivery of reports and carrying out of presentations have been met faithfully for all groups.

According to assessment of the tutors, the groups were able to manage time devoted to the project. Four teachers answered, "strongly agree", while two "partially agree," a "partially disagree" and last "unable to assess", to the question that assessed the ability of students to manage time. When asked about the development of time management capability of students beginning in Industrial Engineering in relation to others, tutors assessed positively (4 respondents agree completely, while two assessed partially agree and two others said it could not assess).

6 Conclusion

The use of PBL applied to freshman class in 2014 in the course of Industrial Engineering, enabled these students to develop the competence project management and the key factors in the first half of the current manufacturing engineering.

It was found that the students had a good search capability, being fundamental to building a strong theorical basis for the project to be developed. It is also highlights the good time management, since all deadlines were properly met.

It was found also that the students assessed that they had difficult with organizational capability, but the tutors rated as good. According tutors, it can be said that the students submitted the project developed organizational capability faster than other students submitted to mainstream education.

Another finding was that the meetings held by groups for project development have lost efficiency, but this may be related to competence with which the group carried out the work, reaching the goal of project before the deadline.

Finally, the most important conclusion is that the analysis shows that the project management competence, so essential in the life of an engineer, was well developed in these new students of an engineering degree.

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Promoting the Interaction with the Industry through Project-Based Learning

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Abstract

Since 2004/05, the Industrial Engineering and Management Integrated Master (IEM-IM) from the Engineering School of the University of Minho, Portugal, has been focusing on the implementation of innovative learning methodologies based on interdisciplinary projects (PBL - Project-Based Learning). The main purpose is to improve the training of industrial engineers, taking into account the competences expected by the professional practitioners. Specifically, different PBL approaches in cooperation with industrial companies have been implemented with students of the 7th semester of IEM-IM, aiming the analysis of problems in the production systems of these companies and the proposal of solutions for those problems. One of this PBL processes include the resolution of a real problem with teams of different engineering degrees. The evaluation of these PBL processes reveals a significant impact on the students' learning, which occurs due to the opportunity to deal with a real context (involving the resolution of industrial problems) that also promotes the development of a different set of key competences to the engineering professional practice. To identify and understand the main difficulties associated with the interaction with industry, this paper intends to carry out a systematic study about the 7th semester PBL projects, considering the perspective of the involved companies. In this way, this study intends to propose a classification of the type of interaction with the companies in the context of interdisciplinary projects, based on the problem definition. The data collection was carried out in the companies involved in the project and took place in before and after the project completion. This work highlights the companies' point of view based on informal conversations and observation, and the information gathered was recorded in a logbook. In terms of outcomes, it is proposed a classification of types (two) of University Business Cooperation (UBC) interaction in the context of learning projects and it is analysed a project with intensive industrial interaction, involving high interdisciplinary requirements and competences development.

Keywords: Project-Based Learning - PBL; University Business Cooperation - UBC; Professional Competences.

1 Introduction

Engineers must be able to develop their professional activities tackling a large set of different types of problems using different competences, i.e. they should be able to mobilize adequate knowledge, methods and abilities, both in industrial and service business contexts. The effective development of competences during the training phase requires adequate curriculum and learning methodologies. Moreover, the development of learning processes centred in knowledge transfer is not enough; it is also necessary to go one step further and apply active learning methodologies, peer instruction, problem and project-based learning (UNESCO, 2010). In this context, Project-Based Learning (PBL) emphasizes interdisciplinary teamwork for problem solving, articulating theory and practice during the development of a project related to a real professional context, or addressing a real problem (Graaff & Kolmos, 2007; Helle, Tynjälä, & Olkinuora, 2006; Powell & Weenk, 2003).

Engineering real problems can be more meaningful if they can be based in the companies' environment, developed in close interaction between university and companies. Thus, students will benefit from the opportunity to work in an industrial environment with different professionals, gaining experience through the application and development of engineering competences, while being supervised by both teachers and professionals. Such environment promotes the development not only of technical competences, that contribute to transform theory into practice (reinforcing the understanding of the theoretical bases), but also transversal competences, like teamwork, project management, critical thinking, problem solving and communication skills. Furthermore, students will simultaneously develop initiative and innovation capabilities.

Naturally, there are some difficulties inherent to the development of projects in real industrial contexts, namely the availability of the company to support the students' teams during their daily routine and communication difficulties related to the alignment of all stakeholders' goals. What would be the benefits that could support the engagement of the industries in the projects with students' teams? Although this question requires a deeper analysis, it is possible to reflect on some potential gains. Industry can engage skilled people that can contribute to improve and innovate their products, production systems and processes. This opportunity of interaction with engineering students and teachers can contribute to renew companies' staff with new ideas, concepts and knowledge, reinforcing the links with university. Moreover, industries will also have the opportunity to help university to define the intended competences for the graduated students.

According to Zabalza (2011) the integration of practice into educational models as been explored with different focus: (1) integrating practice moments within the curriculum, (2) alternating separated training contexts and (3) promoting employability through the development of professional competences and mutual knowledge of actors. Integrating practice moments within the curriculum, classified as *Practicum* by Zabalza (2011), can be pursued by the development of learning contexts based on explicit objectives of integration of curriculum dimensions, involving teachers, students and external professional agents. Several PBL models in collaboration with external agents explore different approaches to *Practicum*; as examples it is possible to find some that explore the relation with services industries (Aquere, Mesquita, Lima, Monteiro, & Zindel, 2012; Lima, Da Silva, Van Hattum-Janssen, Monteiro, & De Souza, 2012), others with industrial manufacturing (Lima, Dinis-Carvalho, et al., 2014; Lima, Mesquita, & Flores, 2014) and others that integrate more than one engineering programs (Soares, Sepúlveda, Monteiro, Lima, & Dinis-Carvalho, 2013).

The Science-to-Business Marketing Research Centre (S2BMRC) conducted a study on the University - Business cooperation (UBC) between Higher Education Institutions (HEIs) and public and private organisations in Europe, for the Directorate General for Education and Culture at the European Commission (EC) during 2010 and 2011. According to the final report (Davey, Baaken, Muros, & Meerman, 2011b), some of the common results attributed to successful UBC "include improving the education and future job prospects of students, the research conducted within the HEI and the transfer of knowledge and research to the community" (p. 8). This report defined eight ways by which HEIs and business cooperate: (1) Collaboration in research and development (R&D), (2) Mobility of academics, (3) Mobility of students, (4) Commercialisation of R&D results, (5) Curriculum development and delivery, (6) Lifelong learning (LLL), (7) Entrepreneurship and (8) Governance. Further, the UBC study presented a set of 30 best case studies of good practice in the area of UCB in Europe (Davey, Baaken, Muros, & Meerman, 2011a). Even though the report states that "developing *activities facilitating students interactions with business* is considered the activity with the highest impact on UBC" (Davey et al., 2011b, p. 23), only one of these cases is related to "curriculum development and delivery". This is an indicator on the lack of studies related to sustainable two-way interactions between universities and industrial organizations centred on students and learning models.

Practicum experiences can be implemented in several different ways in different professional contexts (e.g. medicine, education, and engineering) and they cannot be considered immediately transferable between areas (Zabalza, 2013). Moreover, the number of agents involved, academics, students, and professionals, create a set of complex interactions that must be understood in order to create successful educational processes. In the engineering fields, it is being considered important to develop projects to create meaningful learning opportunities. The classification of types of projects that can be developed in interaction with industrial companies, and its analysis and evaluation, can foster others to implement this type of projects.

This is an exploratory study aiming to describe and evaluate two types of PBL models, which promotes the two-way collaboration between universities and companies and, in that way, contributes to the creation of a classification scheme for University Business Cooperation (UBC) types of interaction, in the context of PBL. With this work the authors expect to build a set of useful suggestions for the improvement of UBC - PBL models, by identifying areas of synergy, fostering new attitudes and changing behaviour regarding university-enterprise collaborations.

The data collection focuses on the expectations and perceptions of the companies involved in these projects in different stages of the project. A researcher has participated in this process as an observer, following the projects and collecting information from all participants, namely from the companies' representatives. Data was recorded on a research diary (logbook) which contains evidences related with situations, conversations and events contributing for an understanding about the relation between university and the industries involved in both projects, particularly about the expectations regarding to cooperation process. For instance, in the meetings the companies' representatives presented their perspectives about the problem solution presented by the students or about teams performance during project development. Thus, the data analysis focuses on companies' perceptions, collected in the beginning and at the end of the projects, considering their expectations, motivations and reflections about the results achieved by the students.

2 Two PBL Models of interaction with industrial companies

The ENGINNOVA project (Engineering Projects of Innovation and Entrepreneurship) refers to a PBL model of university-business cooperation, involving teams of students from different engineering degrees of University of Minho. This project was introduced in 2014/15, with two students' teams and two companies, and was inspired in five similar projects carried out between 2007/08 and 2011/12, under the designation PIEI (Innovation and Entrepreneurship Integrated Project). Each team has a tutor from university and a supervisor from the company. One team was composed by 5 students, 1 from IEM-IM, 2 from IECE-IM (Integrated Master in Industrial Electronics and Computers Engineering) and 2 from ME-IM (Integrated Master in Mechanical Engineering), and the project was developed in a company dedicated to the development of semiconductor devices. The other team had 8 students, 1 from IEM-IM, 3 from IECE-IM, 2 from ME-IM and 2 from BE-IM (Integrated Master in Biological Engineering), and the involved company was a tyre manufacturer. The ENGINNOVA project is illustrated in Figure .

The other type of PBL projects carried out with industry is called IPIEM II (Integrated Project in Industrial Engineering and Management II) involving teams of students only from the IEM-IM. In these projects, teams of 6 to 8 students are assigned to diagnose a production system in one company, then identify an improvement opportunity and implement it. These projects are developed during the whole 7th semester of the Integrated Master degree and involve 5 curricular units as supporting courses (Figure): Production Systems Organization II – OSP2, Production Information Systems - SIP, Simulation - SIM, Ergonomic Studies for Workstations - EEPT, and Production Integrated Management - GIP. Every year 5 to 7 teams of students carry out one of these projects in one local company. Several companies are adhering to these projects from sectors such as electronic, metalworking, equipment producers, shoemakers, textile, plastic injection, and so on.

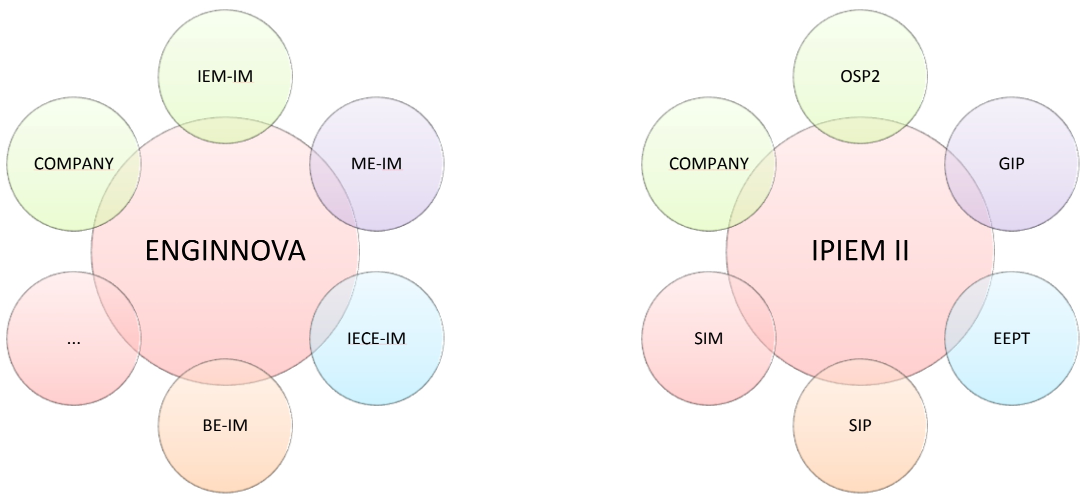

Figure 1: Illustration of two PBL-UBC projects

2.1 Curricular Context and Assessment Model

In the particular case of IEM-IM, the ENGINNOVA project occurs in the 7th semester. The curricular structure of IEM-IM contains 3 unit courses (UC), each with 5 ECTS (European Credits Transfer System), namely Integrated

Project in Industrial Engineering and Management I – IPIEM I (1st semester), IPIEM II (7th semester) and IPIEM III (8th semester), especially included in order to formally contemplate the adoption of PBL approaches at IEM-IM. The accomplishment of the ENGINNOVA project represents 10 ECTS and, for the IEM-IM students, it was defined that those ECTS provide the equivalence to the IPIEM II and IPIEM III UCs. Similarly, the other degrees define which UCs of their curricular structures will correspond to the 10 ECTS of the ENGINNOVA project. The assessment model comprises the following elements:

- 3 Presentations (5%, 10%, 15%)
- Poster (10%)
- Prototypes (25%)
- Report (35%)

Presentations are public and have a 15 minutes duration, except the final presentation (20 minutes), and the entire team should be present. The written report should not exceed 15000 words.

The project IPIEM II is managed by a curricular unit with the same name in the 7th semester of the Integrated Master degree in Industrial Engineering and Management and is totally dedicated to the project. The project however, because may directly involve other supporting courses of the same semester, may end up representing more ECTS credits and that is decided by the course coordinators and student teams.

The assessment model for each team project comprises the following elements:

- 3 Presentations (5%, 10%, 15%)
- Final Report or article (50%)
- Preliminary Report or articles (20%)

The final mark for each team member is then affected by the team peer assessment.

2.2 Projects' Objectives

The purpose of ENGINNOVA projects is the development of solutions for real industrial problems identified by the companies. This includes, as intended outcome, the elaboration of a detailed report describing the proposed solution and a prototype.

This year, the team that worked at the semiconductors company had to adapt an automatic inspection machine designed to work with 200mm wafers so it could also work with 300mm wafers. This involved several modifications, both in mechanical and electronic aspects of the machine. For the team working at the tyre company, the problem to be solved had a very different nature. The company aim was the development of a new process for industrial water treatment. The proposed solution implied technical knowledge from the areas of biological, mechanical and electronic engineering. In both cases, the IEM-IM students were responsible for the project management.

The general project objectives of IPIEM II are basically two: analysing and diagnosing a production unit and then proposing and implementing improvement measures. During the analysis phase, the students' teams cover the production organization aspects (such as material flow and production waste), its ergonomic aspects and the existing management system and flow of information. During the second phase, students present proposals of improvement, and they negotiate with company representatives and teachers the specific action or actions they will develop. During the last academic year, the students' teams developed the following projects integrating contents of the IPIEM II support courses: (1) design and implementation of a production cell in an electrolytic capacitor producer; (2) design an internal material supply system in a tires' textile industry; (3) design a Lean supermarket to reduce space and work in process in a plastic film producer; (4) proposal of a pull production system to improve productivity and reduce work in process in a wiring systems producer; (5) and finally proposed a Lean project management system to manage product development.

2.3 Industrial interaction

Before the beginning of the semester, several meetings between the projects' coordinators and the companies took place in order to define the main goals of the project and the operational details (e.g., it was defined that students' teams in the ENGINNOVA project could visit the companies every Wednesday and companies provide an appropriate workspace). In the early days of the semester a meeting was scheduled in each company with the corresponding students' team, university tutor and company supervisor. After that initial meeting, the team became the main responsible for the interaction with the company, namely in terms of information exchange, rescheduling of visits, etc. Frequently, team tutors also visits the company and interact with company supervisors in order to help in some decisions about project details. Occasionally some teachers also interact with company to clarify specific details of the project. At the end of the project, each team performs a final presentation to company representatives in the company facilities about the mains findings, proposals and results. After this last presentation, companies are asked to report their conclusions and feedback to project coordinator.

3 Definition of PBL Models with Industry Interaction

In this section there is the objective to present two different classifications for PBL models based on the definition of the problem and further to evaluate two specific cases from the companies' feedback.

3.1 Classification based on the Problem Definition

From the document analysis and the cases presented previously, it is possible to identify two main classes of factors that can be used to distinguish the main type of projects of interaction with the industry, based on the Problem Definition. These factors can be used as a framework, both for analysing the success of projects, and to create a type of interaction that promotes the alignment between the direct participants.

It is possible to classify a project of interaction with industry as being mainly: Learning Outcomes (LO) Driven or Industry Problem Driven (Figure 2). This is not an absolute classification, but a relative classification.

In the first case, the coordination of the project wants a problem that allows the students to develop the expected LO and this is a main restriction to the definition of the boundaries of the project, and to the selection of the industrial partners. A great amount of effort should be made, before the beginning of the project in order to find the right partners and to align their expectations. This is the case of IPIEM II, in which the companies should propose a problem that can be analysed by the point of view of the specific project support courses. Moreover, the problem will be solved using and interdisciplinary approach, integrating and merging knowledge and methods of different courses.

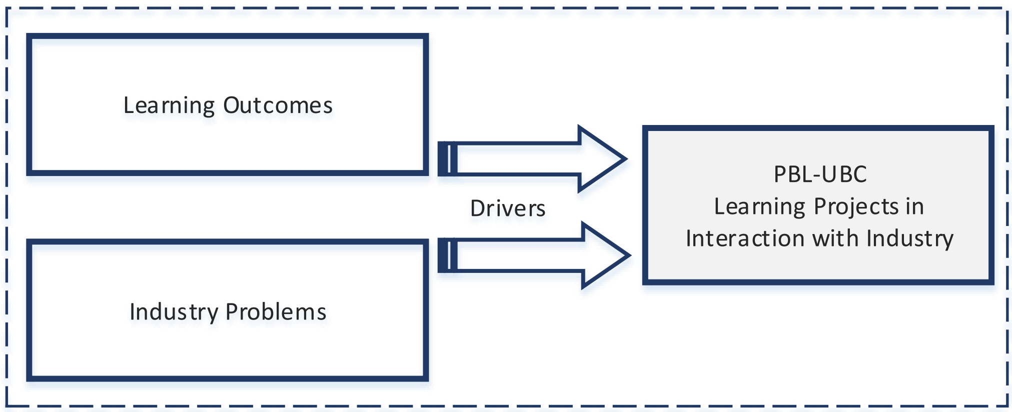

Figure 2: PBL-UBC problem definition drivers

In the second case, the coordination of the project should find industrial partners who want to solve specific real problems with students, supported by academic staff. In these projects, the problem definition effort should be mainly put on the selection of the right set of capabilities. This means that there is a large amount of freedom to accept different problems to be solved and a large amount of flexibility on the type of capabilities that can be mobilized. This the case of the ENGINNOVA project described previously, in which there was two different companies with different type of projects.

Learning Projects can and should have simultaneous characteristics of the both type of factors. If it were possible to find a perfect merge between LO and Industry problem driven projects, than would be a perfect win-win project.

3.2 Companies' Feedback

The feedback from the companies that participated in both projects will be presented in this section. This analysis can contribute to improve the understanding of the interaction with companies, in the context of interdisciplinary projects, and how to improve it, taking into account the two referred approaches: learning outcomes driven and industry problems driven.

The companies' expectations are different in the IPIEM II and ENGINNOVA. In the first project, the companies mentioned that did not expect that the proposals for the problem would be physically tested or even implemented, because there is not enough time and because the diversity of courses directly involved in the project put a specific load on the students' project. Thus, one of the main advantages referred by companies to participate in these projects is to get an external fresh overview on their industrial problems, so that people within the company be aware of them and have some proposal to explore. For the companies that have been repeating the collaboration in these interdisciplinary projects the experience "is being refreshing" (company 5) because the companies have a chance to have a different look about the problems, with proposals supported by knowledge that students developed within the units courses of the semester. In the end, the project results are analyzed by the companies and help them to make decisions with additional relevant information. In some cases, the proposals can be implemented. For instance, for the next semester the company 3 wants a final year student (5th year) to develop the dissertation with the objective to implement the proposals presented by an IPIEM II group. In other cases, the companies dropped some of the proposals because implies resources or did not completely fit in the objectives of the company. In ENGINNOVA project, the companies have high expectations because the focus is the problem. Therefore, they expect new viable ideas for a problem that is not solved yet. This is a clear purpose in the companies' perspective that was mentioned in the first meeting with the students: "bring us knowledge that we do not have" (Company 6). In this context, students have the opportunity to be creative and to think out of the box, in order to achieve an innovate solution for an industrial problem. The results of ENGINNOVA corresponded to this expectation because students proposed a solution that had never been explored before and it not used by any other company in Portugal. The companies also highlighted the importance of this project being developed by multidisciplinary teams because it is closer to the industrial environment.

In the both project approaches (IPIEM II and ENGINNOVA), companies were satisfied with students' performance, beside the results achieved. Words like proactivity, autonomy, professionalism, dedication, engagement were used to refer to their attitude during the process. In fact, the companies expected this performance, but students overcome these expectations by the way they deal and how they face the problems and other unpredictable situations. This is also an benefit of the projects because companies have the opportunity to meet the profile of the future engineers that, otherwise, "is not possible to see in an interview of 30 minutes" (company 2).

4 Final Remarks

The motivation for this study is based on the idea of interdisciplinary projects as a way to promote university and industry collaboration (UBC). The literature reinforces the barriers to this collaboration (Schillinga & Klamma, 2010) and strategies to develop and improve it, are strongly suggested in several studies (Ibrahim, 1998; Meredith & Burkle, 2008; Thune, 2011). The interdisciplinary projects described in this work reveal the importance of this learning approach as a way to develop collaboration with the companies. The different projects presented pointed out different strategies to interact with industries. The IPIEM II is driven by learning outcomes and ENGINNOVA is driven by the industry problems. From the companies' feedback is it possible to identify some similar perceptions for both projects, regarding the opportunity to analyze industrial problems from the "outside". The difference is the approach to the problem. In IPIEM II, students base their proposals considering the content of courses units. The ENGINNOVA do not demand this requirement. Although, in both cases, students have the opportunity to develop technical and transversal competences within a real context, by *practicing the professional practice* (Lima, Mesquita, et al., 2014). The results from the projects also help the companies to identify the requirements and needs of the future, which is a crucial condition for innovation, as mentioned in the 2020 agenda for the Factories of the Future: "*A new European model of production systems for the factories of the future depending on different drivers such as high performance, high customisation, environmental friendliness, high efficiency of resources, human potential and knowledge creation*" (2015-03-01 - http://www.innovationseeds.eu/Funding_Guide/Funding_Sheets/FP7-Factories_Of_The_Future.kl).

The contribution of this paper provides important inputs for future work. There are two main ideas that should be explored. First, analyze the classification of the problems definition considering the perspectives of all participants involved, companies, students and faculty. Second, develop a methodology to assess the impact of the implementation of the proposals by the company, defining indicators that show the importance of UBC experiences.

5 Acknowledgements

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Three years of an intensive Programme: Experiences, Observations and Learning Points

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Abstract

This paper summarizes valuable experiences and learning points from three years of the Erasmus funded Intensive Programme on "Implementing Europe's Future Broadband Infrastructure". The programme consisted of a course held each year 2012-2014 during two weeks of July, where 30-35 students and 10-12 teachers from the 4 participating universities would meet in the location of one of the partner institutions. During the three years, the programme was each year adjusted according to the observations and evaluations from the previous year.

The course was organized as a week of course modules, followed by a week of project work. The topics of the first week were defined to support the project work in the following week. The projects were based on real-life problems proposed by companies, and had to be solved in student groups with a mix of nationalities and educational backgrounds.

Among the key learning points, we can highlight the importance of clearly communicating learning goals as well as motivations for the students to work problem-based and across traditional disciplines. Also, having short time to get a group from four different universities work together it is important to actively encourage (or enforce) the students to mix and work together throughout the course activities. Finally, we found that the model of combining course modules and projects worked well, especially if active learning approaches were used in the course modules.

Keywords: Problem Based Learning, Internationalisation, Intensive Programmes, Cross-Disciplinary projects.

1 Introduction

In the recent years there has been increasing focus on modernisation of higher education in Europe. This is for example described in (European Commission, 2011) which identifies a number of targets, including improving the quality and relevance of higher education, promoting mobility and cross-border cooperation, and linking higher education, research and business. In 2012, we initiated a collaboration project named "Implementing Europe's Future Broadband Infrastructure" (fbi.es.aau.dk, 2014) in the framework of Erasmus Intensive Programmes. This was partly inspired by the challenges as outlined above, but also was done in order to give the possibility to work together for students from different countries in a truly international environment – i.e. an environment without dominance from certain countries or regions. The overall idea of the project was to bring together students and teachers representing different fields of broadband networks and network planning, give an overview of the most important elements in the whole value chain of planning future broadband network infrastructure, and let students from the different disciplines work together on projects by solving concrete business challenges proposed by companies. This way, we aimed to give the students the following experiences:

- Working together across disciplines, and apply their knowledge and expertise in a context where other students would contribute with their knowledge and expertise.
- Working together across different cultures and learning traditions.
- Working together on projects, solving real-world problems.

It also was a good opportunity for teachers to exchange knowledge, experiences, and best-practice regarding teaching methods, with a focus on projects and Problem Based Learning (PBL). It was also crucial to give the involved teachers an insight to PBL which is quite different from the classical lecturer role (Dahms, 2014).

This paper describes the experiences throughout the project and is organised as follows. Section 2 gives an overview on how the project was designed and organised, including a presentation of the expected learning outcomes, course structure, and examination. In Section 3 we present the results extracted from student evaluations, followed by Section 4 that contains a presentation and discussion of the key observations and lessons learned. Section 5 concludes the paper. The main contribution of the paper is the presentation of practical experiences and learning points during three years of the Erasmus Intensive Programme.

2 Project design and organisation

The intensive course itself took place during two weeks in the summer each year in one of the participating countries. In 2012 it was organized in Aalborg, in 2013 in Bydgoszcz, and in 2014 in Barcelona. Each year the Erasmus support would cover the participation of 25 travelling students, and we would accommodate for up to 10 local students (the number of local students varied from 3 to 10 during the three years). The stipends from Erasmus would cover all costs of travelling, accommodation, and subsistence during the two weeks for the travelling students, whereas for the local students the funds were limited to cover the joint meals. In order to facilitate integration and social interaction, all accommodation and meals were organized jointly.

2.1 Learning objectives

With the students having diverse background and learning traditions, it was important to define explicit learning objectives that could be communicated to the students, along with guidance on how evaluation would happen. This way the expectations were aligned and uncertainty avoided, allowing the students to focus on the programme. The learning goals established were the following.

- The students will obtain an understanding of the whole value chain of planning future broadband network infrastructures, enabling them to put their own fields of expertise in a broader extent.
- The students will become familiar with selected real-world problems, and collaborate with students having different backgrounds to develop innovative solutions across traditional disciplines.
- The students will obtain knowledge of different teaching methods, and reflect on their own learning styles.
- The students will improve the competences with respect to entrepreneurship in relation to network planning, in particular by better understanding the relations between technology and business challenges/opportunities.

The first week consisted of mainly course modules. In the second week, the students were working on problem based projects in groups and eventually ended up with (1) a 30-minute presentation that was also handed in as project documentation and (2) a short document with their reflections about the learning process during the project work. The exam was based on an oral presentation and questioning session.

2.2 Course design and programme

The course was generally designed and planned in the same way during all three years, with smaller adjustments regarding both course content and the didactical aspects. In the following we present the course as it was given the first year. Adjustments in year 2 and 3 are explained in Section 3. The basic idea for course design was that of the Aalborg PBL model (Kolmos et al., 2004), where the course modules provide knowledge supporting the students in carrying out the problem based project work. Also, it was inspired by initiatives at the other partner universities, such as the CDIO inititative (Crawley et al., 2007) being implemented at the School of Telecommunication and Engineering in UPC and the experience of RTU with self-organized student groups working on real-world problems (Kapenieks et al., 2002).

The students arrived on Saturday (day 1), and left again Sunday (day 16) two weeks later. There were no or little activities on these two days. Sunday (day 2) was spent on teambuilding and get-together activities, in order to facilitate interaction between students from different universities and “break the ice”.

After this, the first week Monday-Thursday (days 3-6) was mainly focused on course modules including problem solving in groups. In general, one such module was given in the morning session, and another module in the afternoon session. Each module would include teacher presentations as well as group work and problem solving in terms of both larger problems to be solved in the groups, and small peer discussions during the lectures: The design was left to the individual lecturers, but experiments with active learning were encouraged. There were modules regarding technical aspects of broadband networks and applications, as well as business-oriented module. One of the last modules was a guest lecture with a lecturer from industry presenting a topic linking business and technical aspects, and demonstrating how both aspects play a role in handling a specific case. All in all, the topics of the modules were chosen to give the students a good overview of the problem domain they would work on in the second week.

Friday (day 7) in the first week served as the introduction to the project work, including presentation and selection of problems to work on, as well as introduction to carrying out problem based project work with a focus on collaboration in international groups. The project groups got the opportunity to discuss their project organisation, also made a written collaboration agreement between the group members. Especially since many of the students were unfamiliar with PBL, a good introduction to aims, methods, principles and expectations was deemed crucial for success (Du et al., 2007).

The projects were proposed by companies, but in collaboration with the course responsible in order to ensure a good fit with the learning objectives. The project definitions were inspired by (Rienecker et al., 2013), but modified to suit the short project duration. The student groups were pre-determined by the teachers and formed to ensure diversity both technically, country wise, and with respect to gender representation. In addition to ensure such diversity, the main reason for the pre-determined groups was that we wanted to avoid social tension during the course. Each group was free to choose among the different project proposals by handing in a prioritized list, and the projects would then be assigned fulfilling the student wishes as much as possible while also ensuring diversity in the projects to be carried out.

While the weekend (days 8-9) was allocated mainly for joint social activities and excursions, Saturday morning was devoted to an "Entrepreneurship workshop", focusing on practical hands-on use of the Business Model Canvas (Osterwalder et al., 2010).

In the second week Monday-Thursday (days 10-13) the students were working on the project in groups of 4-5 students. They organized and planned the work and tasks themselves, being supported by the supervisor (one teacher) that was assigned to each group. Moreover, since the participating teachers represented different disciplines including knowledge on PBL, they were able to also draw upon other teachers as project consultants, and on representatives from the companies, which had contributed with the project proposals. During both weeks, workshops were held among the teacher to discuss teaching and supervision. The project presentations and examinations took place on Friday in the second week (day 14). One hour was allocated for each group, and was organized by a presentation, questioning and discussion session with questions from the teachers, and then a pass/fail evaluation of each individual student. After the joint questioning and discussion session, it was also possible to have a more open discussion with questions from other students. On Saturday (day 15) the only organized subject-related activity was the evaluation session, with consisted of both qualitative feedback and collection of quantitative data through questionnaires.

2.3 Evaluation

During the two first years, on the last day of the course, the students have filled out a questionnaire to evaluate their experiences, based on a template provided by Erasmus. In addition to the questionnaire, there has been an evaluation session with the possibility to come with more qualitative comments. In the third year, Erasmus changed the evaluation procedure so all students would receive an electronic questionnaire created by the Erasmus Mobility Tool in the days following the course. Unfortunately, some of the questions were different from the previous years, and also the scale was changed from "1-5" to "1-4".

3 Evaluation results and course adjustments

Each year the results of the course were evaluated by students and teachers. The results of student evaluations and changes in the course delivery are presented below for each year. The practical aspects were also evaluated, even though the results are not included here. We have also not included the evaluations of the individual lectures due to space limitations.

3.1 Year 1 (2012)

The main evaluation points from the course in 2012 can be seen in Tables 1-2.

Table 1: Which factors motivated you to participate? (scale 1-5). Average numbers for all students.

	Danish	Latvian	Polish	Spanish	All
Academic	3.7	4.6	4.0	3.8	4.0
Cultural	3.7	4.4	5.0	4.3	4.5
Practice of foreign lang.	2.7	4.2	4.9	4.2	4.3
Friends living abroad	1.3	3.6	1.2	2.6	2.1
Career plans	2.3	4.0	3.9	3.7	3.7
European Experience	2.7	4.6	4.7	4.6	4.4

Table 2: Judgement of outcomes (scale 1-5). Average numbers for all students.

	Danish	Latvian	Polish	Spanish	All
Academic/learning outcome	2.0	4.2	4.4	3.6	3.8
Personal outcome	3.7	4.4	4.9	4.5	4.5
Help in finding job	2.0	2.6	3.7	2.7	3.0
Help in future studies/career	2.3	3.6	4.4	3.6	3.8
Overall evaluation	4.0	4.8	4.3	4.7	4.5

Table 1 illustrates that the main motivations were academic and cultural, and that especially the students from outside the hosting country (Denmark) were also highly motivated from the European Experience. The non-Danish students seem much more motivated than the students from outside Denmark. In Table 2 it is also clear that the travelling students have judged their personal and academic outcomes to be higher than the Danish student. Generally the personal outcomes were rated higher than the academic outcome.

We also had the following important observations that were not included in the quantitative evaluations:

- The students were eager to get to learn new people from other countries, but on many occasions still had a tendency to form “national cliques” – e.g. during meals, seating for exercises, and social activities.
- For the lecture evaluations there was a tendency that the technical lectures were rated higher than the more business-oriented lectures. According to the evaluations, it was difficult for them to see the purpose of the business-oriented lectures especially in the beginning of the course.
- During the presentations and exams some students got extremely nervous, probably because of the exam pressure combined with making their first presentation for a larger audience in English.
- While the students were generally satisfied with both projects and lectures, it was a challenge to find the right level of lectures for such a broad audience with very diverse backgrounds.

With these evaluations and learning points in mind, the program for the second year was adjusted:

- The value of understanding the problem domain from both business and technical aspects were made clearer from the beginning of the course, in order to increase the motivation and satisfaction of the students for the business aspects. This was expected also to increase the academic outcomes.

- To facilitate more integration and communication across national cliques, randomized seating was introduced partly already during the first year (in the last modules of the first week). This was taken a step further by using pre-assigned seating during all lectures, and combined with problem solving in groups of different sizes, to ensure that all students would have the chance to get to better know each other. We would also make an effort to have both visiting and local students accommodated together – which was an option due to lower accommodation costs in the 2nd year due to the location.
- We would focus more on training the students to make good presentations, e.g. through video training.
- For the lectures, it was decided to put even more focus on active learning and peer learning through e.g. exercises and mini projects. In this way, it was expected to increase the learning outcome for students at different levels, also because the students could learn from each other.

3.2 Year 2 (2013)

The main evaluation points from the course in 2013 can be seen in Tables 3-4.

Table 3: Which factors motivated you to participate? (scale 1-5). Average numbers for all students.

	Danish	Latvian	Polish	Spanish	All
Academic	3.6	3.5	4.4	3.5	3.8
Cultural	4.8	4.5	3.9	4.4	4.4
Practice of foreign lang.	2.8	4.2	4.4	4.4	3.9
Friends living abroad	2.6	3.7	3.2	3.0	3.0
Career plans	3.3	4.6	3.3	3.0	3.4
European Experience	4.6	4.8	3.4	4.0	4.1

Table 4: Judgement of outcomes (scale 1-5). Average numbers for all students.

	Danish	Latvian	Polish	Spanish	All
Academic/learning outcome	3.2	4.4	4.1	3.5	3.7
Personal outcome	4.2	4.5	4.5	4.4	4.4
Help in finding job	2.7	3.8	3.2	2.4	2.9
Help in future studies/career	3.4	4.2	3.5	3.1	3.5
Overall evaluation	4.7	4.8	4.1	4.5	4.5

Compared to the first year, the motivations (Table 3) were quite similar, with the overall judgements being a bit lower. However, in general the local participants had a higher motivation than in 2012. Some of the ratings, e.g. "European Experience" and "Cultural" seem a bit lower than the previous year, but this can be explained by the fact that there were more local participants (10 instead of 3), and that the local participants rate these points lower than those who travel. While these quantitative evaluations were very similar to the numbers from 2012, we made the following observations:

- The business-oriented lecture at the end of week one was rated higher than in the previous year. The entrepreneurship workshop was not rated in 2012, but in 2013 it received one of the highest ratings during the week. We therefore believe that we managed to increase motivation and understanding of the cross-disciplinary work. However, this was not yet established when the course started, and the first lecture (which was more business-oriented) was rated at the same level as in 2012.

- The fact that all students, including local students, stayed in the same accommodation, made it much easier to integrate the local students in all activities, which is also reflected in the evaluations from the local students. The efforts to integrate students during lectures also worked out well.
- The focus on preparing good presentations worked: The presentations were better and more fluent than in 2012, and the students were more comfortable and had a better experience.

With these evaluations and learning points in mind, the program for the third year was adjusted:

- We decided to put even more emphasis on the value of working across disciplines, and especially the value of understanding the business and entrepreneurial aspects, from the beginning of the course. Therefore, as a new element, we would add an additional workshop focusing on entrepreneurship already on day 2 (Sunday before the course itself starts). Moreover, the teacher responsible for entrepreneurship would stay throughout the course, to participate in discussions during the first week, and to help focus on entrepreneurial aspects throughout also the second week.
- We decided to increase the video training for presentations, and combine this with pitching entrepreneurial aspects. This was done concretely by ending the afternoon sessions in the second week with a "status pitch" from each group, which was recorded by video and evaluated with the presenter. Moreover, we had several cameras that the students could use for practicing throughout the week, and the opportunity to receive feedback both in groups and one-to-one.
- As an experiment, we would also increase the diversity among students by including students with a more entrepreneurial background as well as students with a bioinformatics background in 2014. This turned out to also give a more equal gender representation among the students.
- We would continue experiencing more with active learning during the lectures.

3.3 Year 3 (2014)

The main evaluation points from the course in 2014 can be seen in Tables 5-6. It should be noted that this year a scale (1-4) is used, which is different from the previous years. However, in the table we have normalised the numbers in order to make them comparable. Also, the local students have not received or filled in the questionnaires, which is all due to changes in the Erasmus forms distributed to students.

Table 5: Which factors motivated you to participate? (Normalised to 1-5). Average numbers for all students.

	Danish	Latvian	Polish	All
Academic	4.3	4.3	5.0	4.6
Cultural	4.6	4.6	4.9	4.7
Practice of foreign lang.	3.2	3.9	4.9	4.0
Career development	3.7	4.1	4.6	4.1
European Experience	4.1	4.3	4.9	4.5

Table 6: Judgement of outcomes (normalised to 1-5). Average numbers for all students.

	Danish	Latvian	Polish	All
Academic/learning outcome	4.4	4.8	5.0	4.7
Personal outcome	4.4	4.8	5.0	4.7
Help in finding job	3.1	3.9	4.2	3.7
Help in future studies/career	3.8	4.3	4.7	4.3
Overall evaluation	5.0	4.8	5.0	4.9

Some interesting observations regarding the last year: Table 5 shows that the motivation regarding the academic aspects is higher in the last year, but also that the judgement of the academic outcome has increased to the same level as the judgement of the personal outcome. The latter has actually increased from 3.7 to 4.7. Even if the local students did not answer the questionnaire in 2014, this indicates a significant improvement. We believe that, at least partly, this can be related to the strong focus on the value of cross-disciplinarity from the beginning to the end of the course – including being very explicit about the learning objective. The increased use of active learning during the first week might also play a role, and we can see from the evaluations that it was appreciated by the students; especially an IT-tool that was used for voting during the lectures received many positive comments. Also, the focus on making video presentations seemed successful, and can have contributed to the higher judgement of academic/learning outcome.

4 Observations and learning points

The intensive programme has been well received by the students, and received good evaluations. Based on the qualitative and quantitative feedback received, there is no doubt that the students have learned a lot:

- Academically, related to the technical subjects
- Regarding collaboration skills in an interdisciplinary and international environment
- Regarding skills related to bring their competences into play when solving real-life problems

During the evaluation of the project, we have made the following observations and learning points, which we believe will be beneficial in future projects that have a similar scope:

- In general the setup with combining courses and projects worked well. However, it is a challenge to give lectures at an appropriate level when the students attending have very diverse backgrounds. This is a problem also encountered in our usual classes, e.g. when having guest students from a broad, or when students from different B.Sc. educations study for the same M.Sc. degree. We had good experiences with integrating active learning approaches and mini projects into the lectures, since this allowed for peer learning that was beneficial even for learners at different levels. However, in the future more personalised approaches to learning could be useful, something that could be implemented using blended learning.
- While the subject-related parts of the course were important, we believe that much of the value was created through the intensity of the program: The students (and teachers) spend two weeks together almost 24/7. Getting to know each other so well also facilitated a good learning environment.
- In our experience it is important to be very explicit concerning learning objectives and goals, and to motivate the multidisciplinary approach. Even if we felt it was clearly communicated, some students would still have an attitude that the non-technical aspects were not relevant for them. Making an effort on doing so, and doing it from the beginning and in 2014 also throughout the course, was probably one of the reasons that we succeeded in increasing the rating of the business-oriented lectures and the overall judgement of academic outcome.
- Two weeks is short time, and it is important to get the students together as a group quickly. For this, the team building activities were good icebreakers. Also mixing students throughout the course – both for group work and seating during lectures – turned out to be a surprisingly efficient way of getting students to know each other and avoid national cliques, leading to both personal and academic gains. This approach was also well received by the students who appreciated and even encouraged this approach.
- It was a challenge to integrate local students. One issue was related to the lack of funding for local students, implying that in most cases they could not be accommodated with the students travelling. Also the local students are in their usual social environment, which makes it difficult for them to become equal part of the group. If at all possible, we would recommend hosting everyone together.
- For communication during the course, we discussed different learning platforms but ended up creating a Facebook group. The immediate advantage was that the user interface was known by most students and teachers, and that it could run on most devices and platforms, including computers, tablets and smart phones. Thus, for spreading information regarding both subject-related and social activities, it was possible

to reach all students quickly. An additional advantage was that it also made it easy to create and sustain friendships, both at an individual basis and by keeping the group active after the course.

- While Aalborg University as a PBL university has a strong tradition for students working on project proposals from companies, this approach was not widely used among the other universities. We increased the number of proposals from non-Danish companies during the three years, but also realized the importance of being very explicit on what exactly was required from the companies, and what they could expect from the students.
- Also regarding the projects and project proposals, we found it somewhat challenging to identify good problems, where the students could come up with reasonable solutions from a workload corresponding to four days of work, and where all students felt they could contribute across backgrounds. Eventually, we developed a common understanding of "concept development" that fit to the time frame and student backgrounds. However, we found it crucial that the project proposals were truly problem oriented, and not just a de facto list of tasks for the students to carry out. It is also important that all supervisors are comfortable with working on problem based work, and has access to other people with PBL experience.
- As a last observation, it was a pleasure to see how the problem based project work motivated the students beyond our expectations all through the three years. During the last days, many groups would spend at their own initiative (and while being in a good mood) long afternoons and evenings on working on projects and presentations.

5 Conclusion

This paper has described our experiences during 3 years of an Erasmus Intensive Programme with focus on letting students work together on projects based on real-world problems across disciplines, nationalities and cultures. The student evaluations were presented, along with our experiences and learning points and it was shown how the evaluations and observations lead to adjustment during the 3 years.

Overall, the student evaluations and judgements of outcomes were high. During the first years the personal outcomes were judged higher than the academic outcome. In the third year we made a stronger effort in making clear objectives and motivating the interdisciplinary approach throughout the course, which might be one of the reasons that the academic outcome was judged higher this year.

The main contribution of the paper lies in the observations and lessons learned, which we believe can be valuable in future projects, e.g. in the scope of Erasmus+ projects as well as in project based teaching and learning activities that enrol in their courses students of different nationalities and backgrounds.

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Sustainability Education in PBL Education: the case study of IEM-UMINHO

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Abstract

Sustainability-related skills are becoming more and more relevant for a proficient and professional engineering practice. Industrial engineers in particular, given their broad field of intervention and being at the heart of industrial activity, hold a great deal of potential and responsibility in providing and delivering best industrial practices, that support enhanced industrial systems and products. Therefore making a real contribution in generating wealth and income for all the companies' stakeholders, including local communities, as well as adding up to more sustainable ecosystems. Previous work by the authors focused on studying the inclusion of this subject on the education of industrial engineers, especially through active-learning methodologies, as well as presenting results on the use of one such approach. The study conducted tried to identify the impacts on sustainability learning using a given specific activity, i.e. a workshop on industrial ecology, held in the 2014/2015 academic year on the Integrated MSc degree on Industrial Engineering and Management at the University of Minho, Portugal. The study uses content analysis of student teams' reports for two consecutive academic years. The former did not include one such workshop, while the latter did. The Fink taxonomy was used in the discussion of results and reflection. The study outcomes aimed at supporting decision making on worthiness of investment on similar education instruments for sustainability competency development. Some results of the study highlight that: (1) the workshop seem to globally have a positive contribution on the sustainability learning; (2) a number of dimensions of the Life cycle design strategy wheel was developed, but the approach was not broadly used, (3) There was a mismatch on the workshop schedule; (4) students enjoy the workshop; (5) a clearer endorsement on relevance of this aspect is required. Suggestions for future work are also issued.

Keywords: Education for Sustainability, Active Learning, Project-Based Learning, Engineering Education.

1 Introduction

It is undoubtable that engineers' education must include sustainability contents. It is also undoubtable that, by one side, changing engineering curricula is difficult and may take long, and by the other side, having a course dedicated to sustainability is not guarantee of full understanding of the message by the students. So, a solution could be to introduce in an existing course unit, the sustainability elements (Allen et al., 2008; Murphy et al., 2009). Introducing these elements in a project through, for example, an active learning methodology, like Project-Based Learning (PBL) (DeFillippi, 2001; Graaff & Kolmos, 2007) is even better since the students will search for eco-efficient solutions, as showed by the study of Colombo, Alves, van Hattum-Janssen & Moreira (2014).

An interdisciplinary PBL strategy has been applied on the first year of the Integrated Master degree on Industrial Engineering and Management (IEM) at University of Minho (UMinho). This strategy has been implemented over more than a decade, on this degree, whose good results were disseminated using a number of publications (Lima, Carvalho, Flores & van Hattum-Janssen, 2007; Alves et al., 2012a; Fernandes, Mesquita, Flores & Lima, 2014; Alves et al., 2014a; Alves et al., 2015). In spite of the difficulties found in this process, such as project management complexity, due to the involvement of many different teachers from different schools and departments (Alves et al., 2015), the coordination team of teachers believe that they are in the right track, by providing a meaningful learning environment for students and a great experience ground, for acquiring competences related with their future professional practice (Fernandes, 2014). At the same time, they learn in an informal way contents considered more demanding, like Mathematics (Cargnin-Stieler, Lima, Alves & Teixeira, 2013).

Additionally, they develop transversal competencies like teamwork (Alves, Moreira, Mesquita & Fernandes, 2012b) and refine others such reading and writing skills (Theisen, Alves & van Hattum-Janssen, 2014). For one such development it is important to engage students on the learning process. To achieve this, the project theme is carefully selected to reflect contemporary and real issues of the society, in order to captivate the students' interest and motivation. This normally targets a real life challenge, such as the ones related with provision of cleaner energy and environmental problems (Moreira, Mesquita & van Hattum-Janssen, 2011). With this focus, the sustainability issues have been introduced in the project. Sustainability learning on the IEM11_PBL was assessed in a study from Colombo, Alves, van Hattum-Janssen & Moreira (2014) targeting the 2013/2014 academic year and previous editions. The outcomes of that study revealed an opportunity to develop deeper understandings and improved application of sustainable practices, when the teams develop and propose solutions for the project challenge. Ways to implement that were also suggested for future editions. The development of the 2014/2015 edition of the IEM11_PBL introduced one such way, i.e. a workshop specifically focused on Industrial Ecology. This paper discusses the impact of this workshop on sustainability learning through the analysis of reports delivered by the students at the end of the semester.

This paper is organized in six sections. Following the introduction, on section 1, a brief literature review on sustainability in Engineering Education is developed on section 2. Section three presents the methodology and section four the study context. Presentation of results, comparison and analysis is discussed in section five, and some final remarks are presented on section six.

2 Sustainability in Engineering Education

The Sustainability, in its various dimensions, especially in the dimensions gathered in the triple bottom line, has been a recurring theme in the context of Engineering, including the profiles of graduates engineering programs. Considering that engineering plays a key role in the development of societies, in terms of technical and economics (aspects well developed on such curricula), but also in social, cultural, political and environmental, it is expected that the professionals from this field, are also trained to realize the development in all the dimensions, i.e. including the social, cultural, and ecological scopes. Therefore, skills aimed by sustainability are also needed by engineers. Engineering education should provide a broader approach in order to consider impact assessment of the solutions, whether positive or negative, in the complex web of life. It is considered that Sustainability is not only a demand; it is also a chance for development of professional competences for a contemporary globalized world. The holistic/systemic approach of Sustainability allows the professionals to consider the various dimensions involved in the solutions. Aware of these requirements of societies, the institutions that guide and make the accreditation of the engineering programs, has included requirements and skills to comply with such demand. The educators of this area increasingly work with the aim of forming socially and environmentally responsible professionals.

The General Assembly of the United Nations, aware of the demand on the issues of sustainability that has become acute in recent years, proposed, in December 2002, the challenge to encourage changes in attitude and behavior in global society, so that we take our responsibilities towards all living beings and nature as a whole. To achieve this challenge, created through Resolution No. 57/254, the UN issued a Decade of Education for Sustainable Development (DESD), developed from 2005 to 2014. During the decade some progress has been made, however, progress is still insufficient. There is still much to work to be done so that sustainability be an intrinsic theme in education, which is why educators are still working on it, and launching new challenges, such as prospects for beyond the DESD, as the medium-term strategies (2014-2021) (OEI, 2010) drawn by UNESCO covering all levels and forms of education (Vilches, Macías & Pérez, 2015). In that, it is our commitment while educators in engineering, working on the inclusion of the theme in educational practices, on dissemination of the results of these practices, and on dialogue with peers.

3 Methodology

Considering a previous study, which specifically targeted the analysis of sustainability competences development on IME first year students, at University of Minho, under an interdisciplinary PBL project whose editions focused on several issues akin to sustainability, a new workshop on Industrial Ecology was introduced in one of the curricular units, specifically addressing Sustainability, Life-Cycle Assessment, Eco-design, among others. Subsequent assessment was intended, using the main project deliverable (the teams' project reports); i.e. whether it resulted in a broader view on environmental issues and a better training in the area of sustainability, which would be expressed on the proposed project solutions and factory plant specifics, or otherwise, remained pretty much the same.

Accordingly, the content of final reports on IEM11_PBL 2014/2015 edition were analysed in order to identify the aspects developed within the phases of the product life cycle and others aspects. Also, a general and comparative overview with the previous editions was done. The Fink taxonomy (Fink, 2003) was used on the analysis of previous study (Colombo et al., 2014). The previous study used content analysis of student teams' reports for two consecutive academic years.

4 Context of the study

The object of study is the Integrated Master Degree on Industrial Engineering and Management (IEM) from University of Minho, in the North of Portugal. The first semester of the first year includes the curricular units (CU), i.e., courses, presented in Figure 1.

Regime	Curricular Unit	Scientific Area	ECTS
year 1			**60**
S1	Algorithmics and Programming	CB	5
S1	Calculus EE	CB	5
S1	General Chemistry EE	CB	5
S1	Integrated Project in Industrial Engineering and Management I	CE	5
S1	Linear Algebra EE	CB	5
S1	Topics of Industrial Engineering and Management	CEsp	5

Figure 1: Curricular units of first semester, first year of IEM Master Degree of University of Minho

As can be observed in figure 1, semester 1 of the first year includes six CU, four classified as Basic Sciences (CB), one (Integrated Project in IEM1) as Engineering Sciences (CE), and one (Topics of IEM) from Specialty Sciences (CEsp). These CU pertain to different schools and departments as shown in Figure 2.

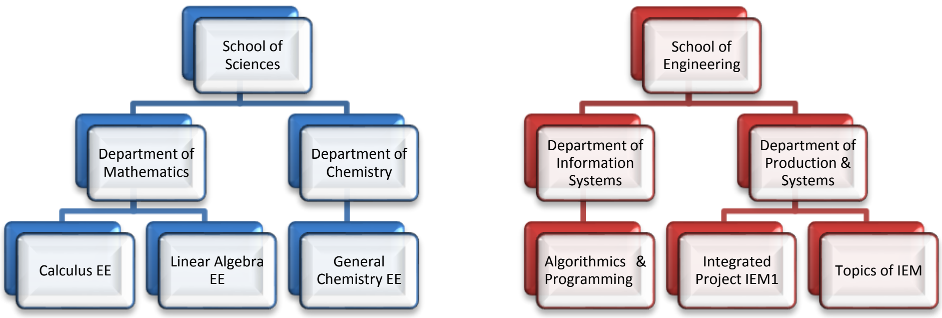

Figure 2: Distribution of CU by schools and departments

All CUs have a workload of five European Credits Transfer System (ECTS) that it is an instrument used to facilitate the comparability of degrees in Higher Education in the European space (46 countries) adopted by Europe after Bologna process. One ECTS represents, normally, 25-30 hours of student work.

The PBL approach is used on the context of the Integrated Project in IEM1 (IEM11_PBL) and all CUs contribute to the project development, with different degrees of integration (e.g. the contents of Topics of IEM is totally integrated). The lecturer in charge of each CU defines the contents to be integrated in the project, and that information is transmitted to the students in the classes and through the project guide. The project guide is a written document, delivered to the students in the first week of the semester, which includes a comprehensive set of information on the full PBL process (coordination team, project objectives and milestones, etc.). For a detailed description of PBL process design see Alves et al. (2014b).

As previously reported, the project theme is always about a real life problem, normally related with environmental concerns. The themes of eleven editions of the IEM11_PBL are presented in Table 1.

Table 1: IEM11_PBL multidisciplinary projects: editions and themes.

Academic Year	Project theme
2004/2005	Specification of a biodiesel production system
2005/2006	Specification of a production system to transform forest biomass
2006/2007	Specification of a fuel cells production system
2007/2008	Desalination of sea water
2008/2009	Production of batteries for an electric car: specification of the battery and its production system
2009/2010	Use of organic waste for the production of bio-alcohol
2010/2011	Air$_2$Water: specification of a portable device for production of drinking water from air humidity
2011/2012	Clean-up and recovery of crude oil from sea spills
2012/2013	Specification of a disassembly line for recycling of WEEE (waste electrical and electronic equipment)
2013/2014	Design of a more sustainable packaging and specification of the production system
2014/2015	Recovery and transformation of cooking oils waste

Each PBL edition may have different design processes, which are not relevant for the specifics of the present study, and can be appraised in Alves et al. (2014b).

5 Sustainability education in IEM PBL

This section sums up the results from a previous study, conducted by Colombo et al. (2014), describes the additional approach taken on the following academic year (new study), and reports, compares and discuss the results obtained from implementation of the two different approaches.

5.1 Summary of results of a previous study

The main results from a previous study on sustainability education in IEM using PBL addressing the Fink taxonomy dimensions, by Colombo et al. (2014), are briefly recapped in Table 2.

Table 2: Summary of the main results from study of Colombo et al. (2014)

Level	Main Result
Foundational knowledge	✓ Some basic knowledge on environmental issues and solutions; ✓ Deep knowledge on sustainability concepts is missing, e.g. sustainable development and environmental impacts, which should establish a strong theoretical ground for the projects.
Application	✓ Some teams applied sustainability concepts and made a good analysis of questions related to sustainability; ✓ Some teams used a broad approach to sustainability; ✓ Students were capable of managing a project, be creative and work on sustainability issues.
Integration	✓ Recognized in some of the projects, depending on the theme and on the teams; ✓ Teams' behavior was different in the way they worked out the theme.
Human Dimension	✓ Social and environmental facets were promoted in PBL, although not in all teams and not with the same depth; ✓ Social dimension of sustainability was observed in some cases, i.e. relating the decision on the plant location and the product, as well as the work conditions of operators.
Caring	✓ Could not be clearly evaluated in the reports, as it implied awareness on how effectively learning and change on values and feelings, was accrued, relating responsible socio-environmental individuals.
Learning How to Learn	✓ Some teams became stimulated and searched means for knowledge construction beyond demand, e.g. made contact with companies that work with similar products; searched for real life problems.

The same study showed that the development of adequate levels of sustainability awareness requires improvements to the learning process. Additionally, it was also clear that more needed to be done to enable students to transform knowledge into competences of devising and applying sustainability concepts. This was the main reason to rethink sustainability education on IEM PBL and propose a workshop specifically targeting this issue, which is explained in the next section.

5.2 Workshop dynamics

The workshop on Industrial Ecology was designed for an audience of about 50 students, involved on the IEM11_PBL plus other 20 students from the IEM first year that were not doing the PBL project). The workshop was developed in three sessions amounting to seven hours of contact, involving the *Topics in IEM* and the *integrated project in IEM1* curricular units. The themes developed were that of: sustainability; eco efficiency; eco design and life-cycle analysis. Several dynamics of the learning process were used, but mainly student-centred one, where the students directly worked one aspect (reflexion, discussion triggered by texts, videos or interactive presentations and exercises). The assiduity on the workshop was not as effective as initially expected. The workshop was assessed on each session and the evaluation was very positive.

The workshop outcomes were investigated, by analysing the reports content, taking into consideration eight dimensions, which are considered on the life cycle design strategy wheel (DEE), as described by Frazão, Peneda & Fernandes (2006). Those eight dimensions can be mapped onto the five stages of the products life cycle. Table 3 presents the summary of the main results from the analysis of the reports over the eight dimensions of DEE.

While complying with the general theme of "Recovery and transformation of cooking oils waste", the teams developed the following projects:

Team 1 – *GlowingRoad*, fluorescent ink for the marking of roads;

Team 2 – *OilEnergy*, thermal plant for production of electric energy;

Team 3 – *InkOil*, production of ink for printer cartridges recycling;

Team 4 – *Ecofire*, production of firelighters;

Team 5 – *BioWheeels*, production of biodiesel;

Team 6 – *ReOils Lda.*, production of detergents.

Table 3: Summary of the main results from the analysis of the reports over the eight dimensions of DEE.

Dimension of the DEE	**Analysis**
Dim 0 **Development of new concepts** (dematerialization, shared use, integration of functions, functional optimization of the product components)	Two groups worked on this dimension, but not exactly following the criteria proposed.
Dim 1 **Low impact materials** (clean materials, renewables, recycling, lower energy content)	The main material was established for all teams and involved the use of a waste material. However, not all groups made a clear statement on the advantages of that. Some teams additionally had some ecological concerns when selecting additional raw materials (natural, renewable and recyclable ones).
Dim 2 **Materials use reduction** (volume and weight reduction)	Two teams have considered this dimension relating the packaging.
Dim 3 **Optimization of Production** (alternative techniques, fewer steps, lower energy consumption, less residues, lower use of water,...)	Mainly focused on aspects of reduction of water and energy consumption, which, to a certain extent, not always/directly linked with the production process.
Dim 4 **Optimization of distribution** (lower need and reuse of packaging, more effective logistics and transportation means)	Two teams have considered this dimension relating the packaging, none reports the improvement of the logistics activity and only one refers the mean of transportation (trucks).
Dim 5 **Impact reduction on use stage** (lower energy consumption, cleaner sources, lower and cleaner consumables,...)	Three teams exhibit concern for improvements on the stage of use by the consumer, while another reports the lower impact of their proposal relating to alternative ones (team 2).
Dim 6 Optimization of the initial lifetime (durability, easiness of repair/maintenance, modular structure, classic design, improved client relations)	This dimension could be instantiated to the nature of the raw material, which was already a waste. However, no team has clearly addressed this issue.
Dim 7 Optimize end-of-life system (recyclability, remanufacturing, reuse, safe incineration)	One team reports use of a recyclable packaging, although not considering other relevant aspects of the packaging LCA, e.g. type of material.

A positive progress was observed on the reports, based on the ones from the previous academic year, in terms of the approaches taken on the improvement of the products, however, not exactly based on the ones proposed on the workshop. The dimensions were worked by the teams, but not in a systematic way and especially not considering the necessary effects of synergies among dimensions that add-up to the overall contribution, or otherwise whose effect of adopting one may introduce a negative impact on the other.

It should be highlighted that Team 2 and 4 worked out the base dimension of *Development of new concepts*, since their product proposals were innovative, specially team 4 that worked out the majority of the dimensions considered in the *Life cycle design strategy wheel*. Team 6 also developed the majority of the dimensions (except dimensions 0 and 5).

It is noteworthy to mention that these are students from the first year and first semester, therefore they are fresher's to the university. Additionally, they do not hold any formal background on sustainability; however the eventual use of tools could have helped on providing greater developments on environmental sound products and processes. Similarly, the students exhibit great concerns on building a project, and respective report, that complies with the requirements of all project supporting courses, and therefore to achieve better results relating product eco design, the workshop needed to be at a higher level of assiduity, and its contents a requirement on the assessment of the reports.

5.3 Comparison and discussion

A comparison of the main results of the two studies is presented in Table 4. Here, the Fink's taxonomy of significant learning was used to express six dimensions of learning.

Table 4: Main results of the studies

Level	Main Results of 2013/2014 and previous editions	Main Results of 2014/2015 edition
Foundational knowledge	✓ Some basic knowledge on environmental issues and solutions; ✓ Deep knowledge on sustainability concepts is missing, e.g. sustainable development and environmental impacts, which should establish a strong theoretical ground for the projects.	✓ Basic knowledge on environmental issues and solutions; ✓ Deep knowledge on sustainability concepts is generally missing, although some exceptions could be observed.
Application	✓ Some teams applied sustainability concepts and made a good analysis of questions related to sustainability; ✓ Some teams used a broad approach to sustainability; ✓ Students were capable of managing a project, be creative and work on sustainability issues.	✓ Most teams applied sustainability concepts and made a good analysis of questions related to sustainability; ✓ Some teams used a broad approach to sustainability; ✓ Some teams denote critical and creative thinking when designing a sustainable product/business.
Integration	✓ Recognized in some of the projects, depending on the theme and on the teams; ✓ Teams' behavior was different in the way they worked out the theme.	✓ Teams were capable of integrating into one piece of work a number of different developments and competences, ideas and new reasoning's, on the search for meaningful solutions. They also connected with real life, at least to some extent, and with other people in the process.
Human Dimension	✓ Social and environmental facets were promoted in PBL, although not in all teams and not with the same depth; ✓ Social dimension of sustainability was observed in some cases, i.e. relating the decision on the plant location and the product, as well as the work conditions of operators.	✓ Some teams equated social, safety, health and environmental proposals, which greatly differ from one another in breadth and depth; ✓ Work conditions was considered by most teams, e.g. when designing the plant.
Caring	✓ Could not be clearly evaluated in the reports, as it implied awareness on how effectively learning and change on values and feelings, was accrued, relating responsible socio-environmental individuals.	✓ Could not be clearly evaluated in the reports, as it implied awareness on how effectively learning and change on values and feelings, was accrued, relating responsible socio-environmental individuals.
Learning How to Learn	✓ Some teams became stimulated and searched means for knowledge construction beyond demand, e.g. made contact with companies that work with similar products; searched for real life problems.	✓ Most teams were highly active in pursuing information, devising meaningful solutions, contacting companies and interacting with lecturers for supporting and directing their own project and master their project specifics.

From the reported results on Table 4, it can be extracted that slight general improvements were introduced to the PIEGI11_IEM regarding the issue of sustainability education. The workshop seems to be one possible instrument to develop such competences. However, the emphasis on what tools teams should use to assess their designs (products and processes) should be made clearer, along with a sharp definition of the project requirements and who is going to assess such issues.

The workshop on Industrial Ecology, where most concepts and tools related to sustainability were introduced, was given starting on week 5 of the semester, whereas the decision on the type of product to be manufactured was generally done at an earlier stage. Therefore, sustainability knowledge was not yet available for supporting product decision making, the other way round was more likely, i.e. the teams could slightly shape only product/processes specifics bearing in mind the prior decision on the product itself.

Overall, the expectations were not fully fulfilled, regarding sustainability competence development, using a workshop. However, bearing in mind that essentially only one CU (out of 5) is specifically targeting the development of this competency, and that the same CU possess many other requirements, one may wonder if the message on the importance of this aspect is coherently assumed by the PBL11_IEM coordination team and, accordingly, transmitted to the teams, and appropriately weighted during assessment.

6 Final Considerations

This study addresses the development of sustainability competences based on an interdisciplinary PBL approach on the first year of the Master Degree on Industrial Engineering and Management, at University of Minho, over two consecutive academic years. For the academic year 2013/2014, and previous editions, a first study was conducted on the same issue. Several outcomes were drawn and some proposals were made in order to improve the results. In the following academic year, a workshop on Industrial Ecology was conducted, targeting a more clear endorsement of sustainability issues by the teams. The main deliverable of each team, the project report, was analysed at the end of the term, and comparisons were made to the previous study, using the Fink's taxonomy of significant learning.

Some results include: (1) the development of aspects of learning on many levels of Finks taxonomy; (2) a number of dimensions of the *Life cycle design strategy wheel* was developed by multiple teams, however the approach was not broadly used, (3) There was a mismatch on the timings of the workshop relating to the moment on decision on product type; (4) the workshop seem to have a positive contribution on the sustainability developments for most teams; (5) the workshop was well evaluated by the students; (6) a more clear endorsement on relevance of this aspect is required.

Regarding future work, although the main deliverable of the PBL project is the final report, there are other deliverables, which were not taken into consideration on this study. Therefore, other instruments can be envisioned to gather a more clear evidence of the outcomes of one such workshop. There was some fuzziness regarding the exact tool to use to assess projects sustainability and report on them. As well as vagueness on weight of such issue on the final grade of the project team. This needs to be clearer.

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Interdisciplinary Engineering and Science Educations – new challenges for master students

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Abstract

During the last century it has been obvious that the global problems are more and more complex and call for problem solvers with educational backgrounds which can meet these challenges, and to meet the challenges many educational institutions have started interdisciplinary educational programmes, but definition of the concept "interdisciplinary" is still needed. This paper investigates the challenges for the students studying a new interdisciplinary science and engineering master programs based on the Media-technology education at Aalborg University. Media-technology combines humanistic, sociological and technical aspects of media technologies. The new master program includes 4 specialities, and one is: Lighting Design. The pedagogical approach of the Lighting Design master program is based on Problem Based Learning and project work in teams. The overall questions dealt with are: How do students understand and use the interdisciplinary approach and how do they carry out a project? In this paper we have described Lighting Design and analysed students first semester projects to see how they solved the problems they have chosen in an interdisciplinary way. The conclusion is that the students can apply the interdisciplinary aspects in their projects, but it cost time and resources, and the consequences are that their projects are lacking a clearer structure and are not quite finished regarding their project goals.

Keywords: interdisciplinary engineering education; problem based learning; master program; lighting design

1 Introduction

During the last century it has been obvious that the global problems are more and more complex and call for problem solvers with educational backgrounds which can meet these challenges, and to meet the challenges many educational institutions have started interdisciplinary educational programmes (Duderstadt 2009), but definition of the concept "interdisciplinary" is still very much needed for students as well as for teachers (Thompson Klein 2009). It seems to be a challenge to define the students' key competences, and the ability of such educations to provide new scientific paradigms and disciplines (Busk Kofoed & Stachowicz 2014). This paper investigates the challenges connected to a new interdisciplinary science and engineering master program based on Media Technology (Medalogy) at Aalborg University. Medialogy, as the education is named, was established 2002 and combines humanistic, sociological and technical aspects of media technology. The Bachelor program includes several aspects of media technology, from topics in human-computer interaction, to math and programming, to courses related to sensation and perception as well as courses focused specifically in one sense (either vision or sound or touch), or courses focused on the design of interactive systems such as digital games and Virtual Reality (Busk Kofoed & Nordahl 2012).

When finishing the Bachelor education students are able to handle several aspects of media technology and are able to solve problems in an interdisciplinary way.

The master program today includes 4 new specialities: Medialogy, Service System Design, Sound and Music Computing and Lighting Design. (Study regulation 2014). The bachelor programs as well as the master programs are based on Problem Based Learning and project work in teams (PBL).

In this paper we will focus on the Lighting Design master students and their way of using the interdisciplinary aspects in their study. The students have different backgrounds at Bachelor level as well as different nationalities when starting the master. Some of the overall questions dealt with are: How are the master curriculum designed and how do students understand and use the interdisciplinary approach and combine the different disciplines when working with a problem in their projects?

Experience from the Media Technology (Medialogy) master show that interdisciplinary studies are a challenge for the involved students who traditionally have a background within single disciplines and therefore they need to develop a new skillsets to see the possibilities of creating new interdisciplinary based knowledge. Another challenge is to establish a new identity within the interdisciplinary educational concept. In this paper we will address these problems using educational theories (Busk Kofoed & Nordahl 2012, Barge 2010, Kolmos et al 2004) and a study from a new interdisciplinary master education within the engineering and science area. The overall question is how to define interdisciplinary engineering educations. The underlying questions are related to the implementation of interdisciplinary teaching approaches in practice: how do students use the learning in their interdisciplinary projects. We will use experience from Medialogy (Busk Kofoed & Nordahl 2012) and will use the master speciality; Lighting Design *as a case.*

First we present the theoretical concept of interdisciplinary educations and the pedagogical approach. Then we describe the master speciality; Lighting Design and describe as well as analyse the students' projects from their first semester. Finally the results and the challenges for the students as well as for the teachers will be discussed.

2 Interdisciplinary educational approach

In recent years a number of interdisciplinary educations have been developed worldwide especially in HCI and related fields (Winograd 2008). However it is still a challenge to design an interdisciplinary curriculum which at the same time has a coherent and progressive curriculum (Larsen et al 2003). Many interdisciplinary educations are merely a combined effort of putting together different competences from several faculty members. When starting planning an interdisciplinary education it is important for the planners to have a fruitful cooperation and a common understanding of the terms. Within a program, e.g. HCI, it is also a challenge to find the core competences in a curriculum which has to contain elements from engineering as well as human factors. As an attempt to bridge the gap, Pausch and Marinelli describe how they in their HCI Master education started by teaching basic programming to artists, and humanistic subjects to computer scientists. However, this solution did not prove to be ideal. Instead, they preferred to mix the different profiles during students project work (Pausch & Marinelli 2007).

The terms *interdisciplinary* and *trans-disciplinary* are often used interchangeably. In this paper we adopt the definition proposed by Meeth who by observing and analyzing the existing confusion is defining what an interdisciplinary education is (Meth 1978). Meeth proposed a hierarchical classification, illustrated in Figure 1. At the bottom of such hierarchy he placed intra-disciplinary studies, i.e., studies composed of a single discipline. At a higher level we find cross-disciplinary studies, i.e., studies in which one discipline is viewed from the perspective of another. An example of a cross-disciplinary study is, as Meeth mentions, the study of the physics of musical instruments. Cross-disciplinary studies are relatively easy to establish, since they allow faculty members to remain in and use their own disciplines. At the next level he placed multidisciplinary studies, i.e., the juxtaposition of disciplines, each offering their own viewpoint, but with no attempt of integration. One level higher shows interdisciplinary studies, which is an attempt to integrate different disciplines in a coherent and harmonious curriculum of several disciplines which allow solving a particular problem. According to Meeth, the highest level of integrated studies is trans-disciplinary studies. Such studies go beyond disciplines, since they start from a problem and, using problem solving approaches, they use the knowledge of those disciplines which can contribute to the solution. Therefore while interdisciplinary studies start from a discipline and develop a problem around it, trans-disciplinary studies start from a problem and find the related disciplines which facilitate solving it.

As also argued by Meeth, trans-disciplinary studies are hard to design, since they require highly prepared and intellectually mature faculty members as well as students. Interdisciplinary and cross-disciplinary or multi-disciplinary concepts are often used without considering their meaning. It is important to have a clear definition and understanding of those words when being in an environment trying to establish a common understanding of a new education with a new combination of disciplines. This counts for teachers as well as for students. In this paper we will use the definitions proposed by Meeth in 1978 when discussing how to use a curriculum.

5. Transdisciplinary studies
4. Interdisciplinary studies
3. Multidisciplinary studies
2. Cross-disciplinary studies
1. Intra-disciplinary studies

Figure: 1 Representation of the hierarchical educational structure as proposed in Meeth [12].

The remaining question is which pedagogical approach can support and ensure the integration of the content in an inter-disciplinary and cross-disciplinary education.

Our presumption is that the Problem Based Learning approach (PBL) represents an ideal framework to design an interdisciplinary education close to being trans-disciplinary in the sense defined by Meeth (1978), where trans-disciplinarity and inter-disciplinarity is viewed as the ability to define a problem and find the relevant disciplines which allow solving it.

3 Problem Based Project Organized Learning approach

Problem Based Project Organized Learning (PBL) has been widely adopted in several educations worldwide, among other things for its ability to develop problem solvers and for giving the possibility for students to work in groups when solving issues close to the real world. PBL has especially proven to be particularly suitable for educations dealing with design of complex technical problems in multidisciplinary settings (Schultz & Christensen 2004, Stachowicz & Busk Kofoed 2014)

In Media Technology education the Problem Based Learning (PBL) pedagogical approach (Barge 2010) is a basic prerequisite in the education and has been used as a main pedagogical approach since the start of the education in 2002 (Nordahl & Busk Kofoed).

PBL support students to work with a problem and to structure problems in such a way so they are able to integrate and apply knowledge from different disciplines. This allows students to see connections among disciplines and promote the carryover of knowledge from one discipline to another. In this situation, PBL facilitates interdisciplinary studies, since students are exposed with a problem, and need to find the relevant disciplines and connections among them which allow solving the problem. Most of the problems addressed by students in the different semesters are interdisciplinary by nature, since students start from a given theme, finding a problem to solve, analyze and use several disciplines to address it and solve it – of course always facilitated by a teacher. Each semester has a theme and the students choose a problem related to the theme. Students have to analyze the context of the problem to find the best solution, so problems chosen by the students are normally rather complex and need several disciplines to be solved. Students get a 5ECTS course about project work in groups when starting in the first year of their Bachelor education. The new master students get an intro course of three days to PBL, so it can be hard for new students to start with a new pedagogical approach and at the same time get used to the interdisciplinary master in Lighting Design.

4 The master in Lighting Design

The planning of the new master in Lighting Design started 3 years ago and was implemented September 2014 (Hansen 2013).

The biggest challenge in the planning phase of a new master in "Lighting Design" was to establish a common vision and goal among the involved teachers from different faculties, and get them to see how their different expertise could generate synergy. It took time and effort to get a common language and to understand each other's expertise as well as finishing the discussion about the value of each teacher's expertise in the new education. Most of the teachers in the planning group had many years of experience from their respective research and educations, so to get this common understanding was a hard barrier to overcome. According to the head of the planning group, the PBL pedagogical approach has been and will be the cornerstone which can connect the faculty and the ideas in the education, and according to the teachers it is still difficult to see the overall curriculum and find your own teaching strategy "you have to establish a new identity". (Busk Kofoed & Stachowicz 2014). After one semester members of the faculty are still having a hard time to get their courses connected with the interdisciplinary curriculum so the teaching has an interdisciplinary approach and content.

The Lighting Design Master has duration of 2 years, and is following the Aalborg Model based on Problem Based and group organized Learning (PBL). Semester 1 and 2 each has 3x5 ECTS courses and 15 ECTS project. Semester 3 has 2x5 ECTS courses and 20 ECTS project. The 4th semester has a 30 ECTS thesis project (there can be variation for the thesis project). Each semester has a project Theme, to which the projects have to relate (Study Regulation 2014). The themes are:

1. Semester: Seeing the light.
2. Semester: Creating with light: Interactive Lighting.
3. Semester: Lighting Design Innovation.
4. Semester: Thesis – own choice

Table 1: Competence profile of the graduate of the master's programme

Knowledge	**Skills**	**Competences**
Must have knowledge of theory based on the highest international research in relation to designing with daylight and electric light in virtual and real space.	Must master the lighting design scientific methodologies, tools and general skills related to employment within the field of lighting design	Must be able to manage work situations and developments that are complex, unpredictable and that require new solutions that can be used to explore and exploit the great potential of new lighting design with a media- and light technological, architectural and sustainable approach.
Understand and synthesise at the highest international level the knowledge of light in the subject areas of architecture, media technology and engineering.	Must be able to evaluate and select among theories, methods, tools and general skills to create new lighting analyses and solutions.	Must be able to independently initiate and carry out discipline-specific and cross-disciplinary collaboration by combining the art and science of designing with light.
Be able to critically relate the knowledge, and understand the importance and potential of artistic and scientific innovation, creativity and entrepreneurship in designing with light.	Must be able to set up new analysis and solution models on a scientific basis.	Ability to apply acquired knowledge in research, innovation and practice.
Be able to identify scientific issues across the subject areas by designing with light.	Must be able to discuss professional issues across disciplinary research-based and practice related knowledge and discuss professional and scientific problems and solutions with both peers and non-specialists.	Must be able to independently take responsibility for own professional development and specialization in lighting design.

Table 1 shows knowledge, skills and competences which a graduate master candidate will have according to the competence profile of the program. According to the program the curriculum has to be based on interdisciplinary teaching and learning. And the question is if it is implemented as such.

In the homepage for the education (Fig 2), it is interesting to see how the interdisciplinary program is illustrated, explaining the content of the study (Hansen 2013). The courses are based in 3 columns which indicate the 3 different areas which compose the new education; Lighting Design. The semester project covers all 3 areas, so the idea is that it is in the projects the students have to establish the interdisciplinary dimension. The students have to apply the knowledge gained from the 3 courses in their semester projects. The interesting question is how will the students solve this challenge?

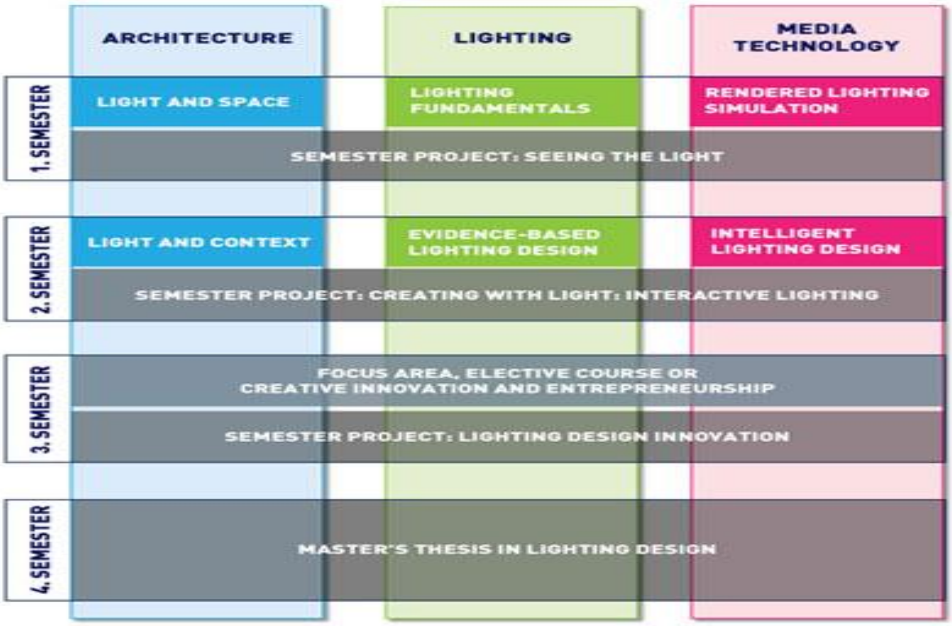

Figure 2 show the 3 different areas which compose the Lighting Design Program (Hansen 2013).

4.1 Student's 1. Semester projects

28 students divided in 7 groups made their first project within the theme "Transforming with light". The students came from 14 countries, and 89% of the students had experience with different kind of group work.

All students should work with transforming a specific church in Copenhagen into something that would add value to the community in the city area and at the same time the students should develop skills and understanding in designing with light by synthesizing the fundamental principles of lighting design from fields of architecture, lighting, science and media technology. According to the study regulation, the students in their projects must show they understand the complexity and possibilities that lie in the interplay between the specialized fields. The students have to combine the art and science of designing with light in real and virtual spaces.

In the following we analyse the 7 projects according to 4 goals in the study regulation: *1*. The project groups Final Problem Statement (FPS). *2*. Elements in their analysis of the problem chosen. *3*. Topics used in their design of the problem solution. *4*. Accomplishments of testing/ evaluation of their solution.

Table 2: content of the students' projects.

Project group	Final Project Statement	Analysis	Used topics	Implementation and test
Group A: Group of 3 students Title: Family Space	Problem statement: How can light be used to transform the church building into a space that facilitates two different environments for families on Vesterbro with children between the age of 3 and 7 years (both included)?	Target group. Building analysis. Influence of light. Physiologic and aesthetic. Natural light. The most powerful source to activate or deactivate a person. Level of energy. Children's need.	Lighting fundamentals: environment with children, daylight- artificial light, colour. Light and space, design method. Rendering, light experiments – renders in 3DS max for testing	Difficulties with reliable tests. Future development is mentioned.
Group B. Group of 5 students Title: Climbing Absalon	How do we accommodate the use of daylight and artificial light in a climbing space in order to achieve the requirements for a sport facility without causing glare?	Target group. Building analysis Guiding with light. Daylight and artificial light. Vertical, concave and convex illumination.	Lighting fundamentals, luminaire search, light fixture tests. Autodesk Revt Architecture. Interactive climbing holds. Rendering Rhino and 3ds Max models	Test – re-design is suggestion. Future developments are suggested.
Group C Group: 4 students Title: Redefinition of a ceremonial space	Can we transform religious space into a religion neutral ceremonial space, satisfying new ceremonial needs of our society through the use of light?	Target group. Building analysis. Light in a building. Heritage and light. A ceremonial space. Religion neutral space. A funeral ceremony. Emotional, visual elements. Attention and distraction. Neutrality and lighting. Success criteria.	Lighting specifications, tests, dynamic diffusing (dynamic, controlling, software interface). Meterial, PDLC-Arduino - electric elements. Rendering VR- models.	Uncompleted test, no external evaluation. Proposal for further development.
Group D Group of 5 student Title: LINDIN bath	Is it possible to implement therapeutic light with high intensity and changing light, and at the same time create a relaxing environment for the visitor? (3 success criteria)	Target group. Building analysis. Light and health. Healing architecture. Interactive lighting design.	Light therapy. , light intensity, Light environments. Light adaption. Spatial dimensions. Design. 3D max, modelling, simulation, tests, rendering.	Testing success criteria based on renderings. Proposal for future development.
Group E Group 4 students Title: Local Study room	How can light support a flexible space for studying? (3 success criteria)	Target group. Building analysis. Learning environment.. Acoustics. Focus groups. Analogue and VDT-based work.	Spatial dimensions. Light and shadow. Different light sources. Materials - , spaces, 3D modelling. Rendering of models.	Based on the tests of 3 scenarios few improvements are proposed
Group F Group 3 students Title: Dark to Light: an experiment in lighting design.	How can we divide a space by the use of light alone? (3 success criteria)	Target group. Building analysis. Theatre lighting- Bright and dimmed light. Psychology of light. Light as a structural element.	Lighting specifications, The human eye, light adaption, dynamic diffusing (dynamic, controlling. Model with Arduino and led. Luminance levels. software interface). Rendering.	Test – limitations of rendering models are discussed. Proposal for a redesign.
Group G Group 5 students Title: Audio Park	How can we create an atmosphere in the Audio Park that are inspired by the Nordic Light, sky and landscape and which can make the visual and audio senses work together? (3 success criteria)	Target group. Building analysis. Outdoor space Nordic light. Visual and audio senses. Audio Park concept.	Analysis, 3D space, spatial properties of Nordic light, diffusing light, colours. Pocket Parks. Space dividing Lights. Construction of ceiling structures. Rendering simulation, lighting solutions, lab tests (without users).	Testing rendered 3DMax experiments. Technical difficulties did cause lack in simulations. Proposal for re-design.

4.2 Evaluation of student's 1. Semester projects

All the projects have a clear final project statement, which is the core element for the design of a solution. Furthermore all projects have made an analysis of the problem area, which is very important for understanding how to handle and work with the different aspects connected to the final problem statement and which is also important for deciding how to test the solution. It seems that all projects have elements from all three course areas, but based on different perspectives and therefore with weight on different details. Almost all project have problems regarding testing their solutions, and the causes are explained to be lack of technical equipment, lack of time, lack of organizing a proper test situation. All projects have proposals for redesign and future development of their projects. It is obvious that the students would need more time for making their first semester project. They need more experience in planning and organization of a project. The beginning of the projects is fine and well structured, but during the project it seems to be less structured and the clear focus is somehow disappearing. Though when evaluating their project, the students are aware of the missing elements in their projects.

It is the student's first Lighting Design project. In a small survey made after the exam the students indicate that it has not been easy. The answers point to some of the problems related to project work like cooperation and communication which are confirmed of the answers from the question in the survey. One question was: Which was the most important skills to get your project group to function?

"It can be a big challenge to cooperate with such a wide spectra of people with different nationalities and educational background. I think it will be good to narrow the admission requirements for the next class of lighting designers". (student c)

"For the first semester group project, our communication was horrible. Likely because there were so vastly different backgrounds in the group that it was very hard to communicate". (student s)

"It has been difficult to develop ideas in groups, where many don't have practical experience and depend on other to do some more works. It wasn't optimal at all, and I can't agree with this group work". (student F).

Despite the new way of work and study and all the challenges connected to the first project, the students find the content and approach good, interesting but challenging.

"you have to work very hard, but interdisciplinary work is the way in the future" (student H)

5 Conclusion

According to the definition of interdisciplinary educations we can conclude, that the master in Lighting Design is an interdisciplinary education, if the students are able to incorporate all elements in their projects. The projects had elements from the three courses; Light and Space, Lighting Fundamentals and Media Technology, so the students' first semester projects seem to have reached almost the goal according to the study regulation.

In all projects it is stated that students needed time and resources. The lack of time and resources (technical as well as other non-technical) is vital for making a good project within the given time frame. Another point is that for many students it is their first project using PBL and an interdisciplinary learning approach. It was the first semester for both the students and the teachers, so the future first semester projects work should have more support for planning and structuring a project, so the students can make a realistic plan for the whole project. It can also be concluded that the skills needed for project work have to be emphasized and trained as the students find them as the most important skills to get a project group to function.

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Combined Work and Study Learning approach, a new model to achieve professional skills in Engineering Education

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Abstract

Once Mondragon Unibertsitatea adapted its Engineering Degrees and Master's Degrees according to Bologna Declaration, the implementation of the new pedagogical model took place. Mondragon Unibertsitatea has always encouraged part-time work among its students and therefore, one of the actions was to promote the Combined Work and Study Learning (CWSL) approach, based on the philosophy of WBL (Work-Based Learning), whereby the learning through work is taken into account as part of students´ learning process.

This paper is aimed at analysing the CWSL approach implemented in the Industrial Engineering Master's Degree of Mondragon Unibertsitatea, in which the percentage of students taking part in the approach is higher than 50 %. This approach is a three-way partnership among the company, the student and the university. First, the CWSL approach is described: requirements, application, assessment, supervising method… all these being highly conscious of the key role that the person in charge in the company has, through their commitment and collaboration. Then, students' learning process is discussed based on academic marks and specific questionnaires, which are used to analyse the development of technical and non-technical skills. In addition, the satisfaction of companies is evaluated through specific inquiries. The results show that students involved in the CWSL approach fulfil academic objectives satisfactorily and most importantly, they improve their skills with work experience. This is possible because they learn to work more efficiently as they have less time available.

Keywords: Combined Work and Study Learning approach, Work-Based Learning, professional skills.

1 Introduction

The Faculty of Engineering of Mondragon Unibertsitatea has always encouraged part-time work among its students by blending work and study.

However, this experience was not included in their academic curricula, despite considering it very rewarding. Thus, those students who coped with studies and work assumed their job as an extra responsibility for them in exchange of financial compensation. In fact, the university did not reflect in their curricula any academic competences and the professional skills the students had acquired.

Once the Faculty of Engineering of Mondragon Unibertsitatea adapted its Engineering Degrees and Master's Degrees according to Bologna Declaration, they implemented the Combined Work and Study Learning (CWSL) approach based on the WBL (Work-Based Learning). WBL is the term used to describe a class of university programmes that bring together universities and work organisations to create new learning opportunities in workplaces (Boud, Solomon, 2001).

Raelin asserts (Raelin, 2010) that work-based learners display certain features: they tend to want a challenge, have commitment, are consistent in their beliefs and actions, are risk oriented and naturally collaborative. Organisations that adopt WBL approaches tend to value collaboration over individualism, and have clarity with regard to mission and goals.

In addition to all this the advantages of WBL programme are the following:

- Development of skills and abilities in a real industrial environment.
- Application of knowledge acquired during theoretical lectures.

- Development of non-technical skills directly related to the work environment, such as project management, decision making, negotiation skills and teamwork.
- More motivated and committed students to their own learning process.

1.1 General background

The history of the beginnings of WBL for academic credit is set in the rapid change in the social and economic context and hence the education life in the UK during 1980s. It covers the period between 1980 and 1988 with a timely and pragmatic initiative to demonstrate the validity of the claim that learning at a higher education level can occur in the workplace (Boud, Solomon, 2001).

After this first documented experience WBL has been implemented in several countries and university systems but it is clear that although WBL represents a substantial and provocative innovation in higher education, it has not been a subject of much research.

Besides, the *Triple Helix* thesis is being applied in the most developed countries as an innovative and successful pattern to handle the knowledge to enrich the country. The *Triple Helix* is a spiral model of innovation and economic development in a Knowledge Society based on the reciprocal relationships between University-Industry–Government to generate new institutional and social formats for the production, transfer and application of knowledge (Etzkowitz & Leydesdorff, 1995). The objective is to highlight how important this connection among companies, government and universities is for the creation of new knowledge and innovative activities for the development of a country.

Combining work and studying is a common practice in Northern European countries, which are well known for their innovative education system. Figure shows the percentage of young people who blend study and work in different countries and there are significant differences between them. It may represent a trend in the countries that enhance WBL in the higher education taking into account the cohort of 20-24 years old.

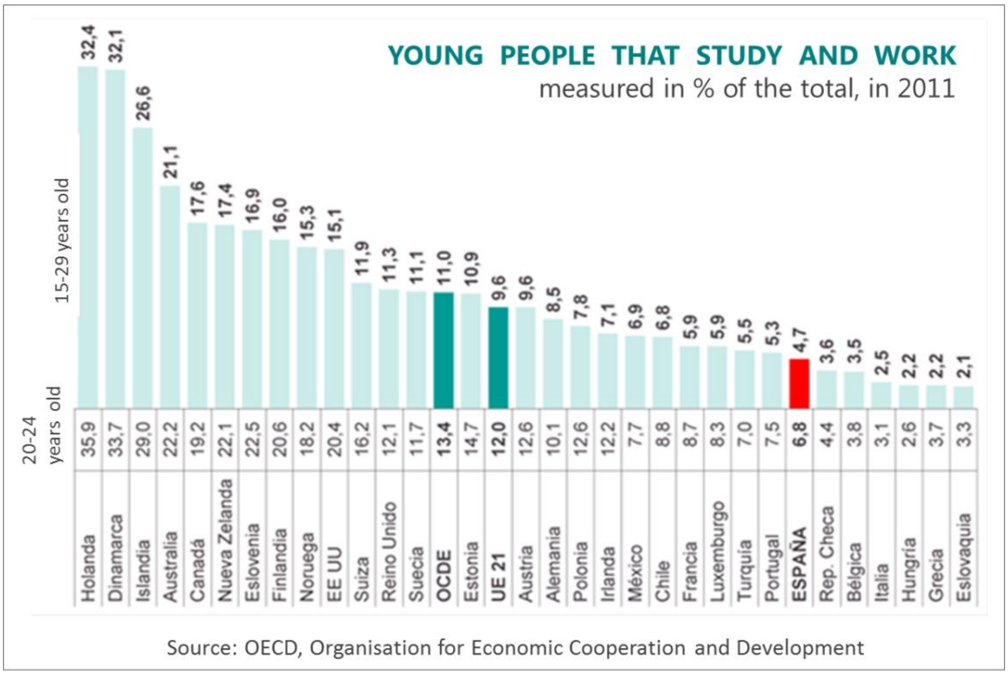

Figure 1: Young people blending studies and work (OECD, 2011)

The Basque Government is already working on the *Triple Helix* implementation. Up until now, *Hezibi* programme is implemented based on WBL model and it is being run in professional trainings. Thus, we can state that the Basque Government is committed to go ahead with WBL programme. Moreover, an specific agreement among UPV-EHU University, a company and Basque Government has just been signed which can be a good chance to apply the WBL approach in higher education.

1.2 Motivation

The Faculty of Engineering of Mondragon Unibertsitatea is part of the Mondragon Corporation, the tenth-largest Spanish Group in terms of turnover, so it is very close to the industrial environment. As stated in the last Strategic Plan of the Faculty of Engineering, the principle target of its mission is the comprehensive training of engineers and technicians and a lifelong learning as key elements of social development. To our mind, to achieve this target WBL has a prior importance.

The relation between the Faculty of Engineering and the companies enhances students to blend work and studying during their studies. In fact, Alecop S. Coop. is a company which, in collaboration with the university, helps students find a part-time job. Moreover, Alecop S. Coop. has also designed a non-curricular programme known as *Ateko*, with which students develop professional skills. Figure 2 shows *Ateko* programme's professional skills.

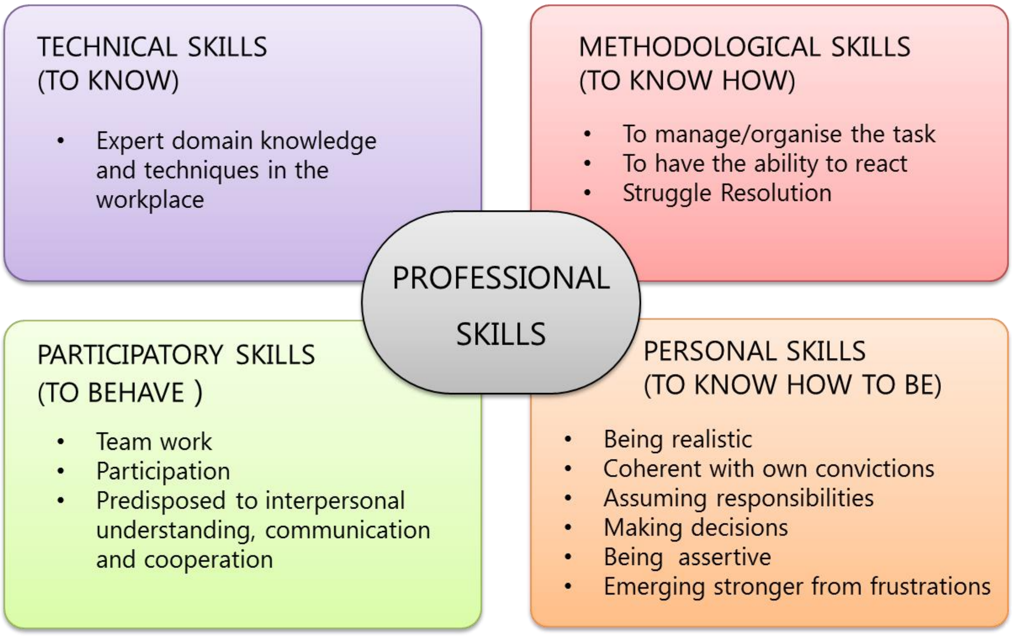

Figure 2: Professional skills defined in Ateko programme (courtesy of Alecop S. Coop.)

The objective of this paper is to analyse the results of CWSL programme considering the results in the Industrial Engineering Master's Degree in Mondragon Unibertsitatea. For that purpose, the satisfaction of the students and the supervisors, and also students´ academic results have been analysed in detail. Nevertheless, the most important fact is to ensure the best level of technical and non-technical skills of these students.

2 Combined Work and Study Learning approach

Combined Work and Study Learning approach gives students the opportunity to learn a variety of skills by expanding the walls of classroom learning to include the community. By narrowing the gap between theory and practice, WBL gives sense to students. Under the guidance of supervisors, students learn to work in teams, solve problems, and fulfil employers' expectations.

The participation in this programme is not compulsory, it depends on the student's will. *Figure 3* shows both modalities of the semester in Industrial Engineering Master´s Degree, i) the standard semester organisation modality, where the student attends classes, academic activities (laboratory practice, speeches, company visiting…) and carries out the whole PBL (Project Based Learning) project , and ii) the CWSL approach, where the student works part-time blending study and work. The work-based learner is freed from certain academic tasks, due to being working and studying, as it is assured the student acquires all the curricula´s technical competences.

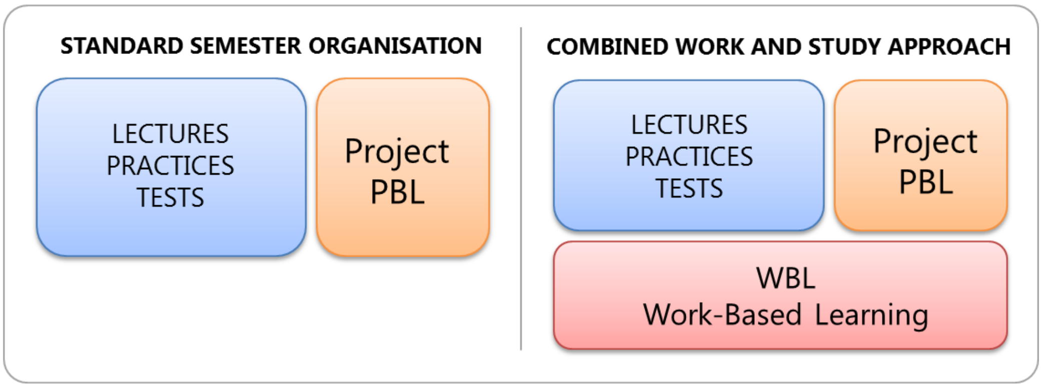

Figure 3: Standard semester organisation vs CWSL approach

When students apply for the CWSL programme they have to define the company´s main activity, the department where the activity will go on, the contact of the person in charge, the tasks that will be carried out in the workplace and the competences related to their job during the trainee period. These tasks must be in concordance with the Master´s Degree's main technical competences in order to be accepted by the university. The university assigns a tutor to do the follow-up during the trainee period.

At the end of each semester the students have to make a report and, also, an exhibition in front of the tutor and classmates sharing their experiences, learning and reflections. In addition, the university tutor organises a meeting with the company´s supervisor to assess and analyse the student's development in the workplace. At the same time, the tutor checks the student's learning outcomes, behaviour, development, marks… to assure the student's learning process is properly going on. Afterwards, a feedback is given to the student and if there is any problem, whether in the workplace or with the academic results, the student is removed from the CWSL programme.

At the end of the CWSL programme this work experience is attached to the student´s diploma.

3 Work definition and technical competences

As explained previously, when students apply for the CWSL programme they have to indicate the competences they will work on at the company or in one of the lines of research of the university during the trainee period. If we consider the Industrial Engineering Master's Degree of Mondragon Unibertsitatea on the CWSL programme from September 2014 to February 2015, the several competences that have been worked are grouped and shown in Figure 4. The competences related to Machine and Structure Design were the most worked ones (35 %). The competences within the field of Materials and Manufacturing (22 %), and Production Management (19 %) were also relevant.

Most importantly, these results are in agreement with the education programme of master's degree taught at Mondragon Unibertsitatea, which offers two specialisations: i) Mechanical Design, which is directed towards machine and product design and verification; and ii) Materials and Manufacturing Processes. In addition, the results observed in Figure 4 respond to the demand of the industry network of the Basque Country. In fact, the basque industry is characterised by having important enterprises developing machine-tools and manufacturing processes.

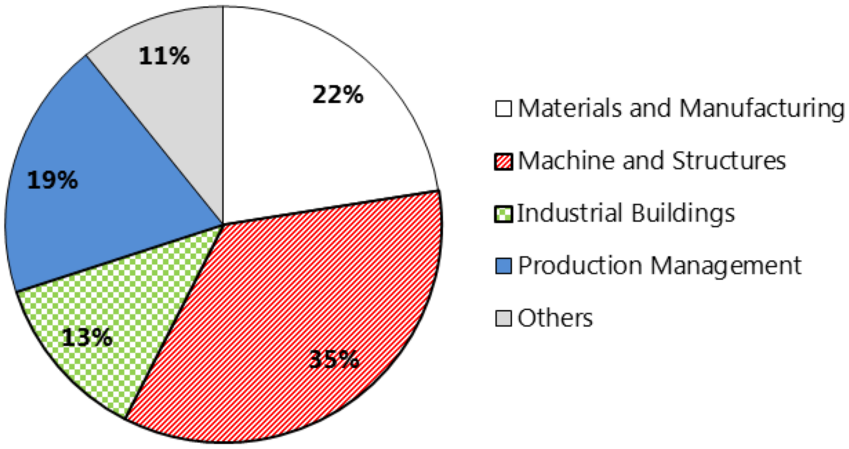

Figure 4: Distribution of the competences, grouped in fields, the students were working on during the CWSL programme

4 Methodology

In order to assess the experience of CWSL from the students' point of view, a survey was conducted to 61 students who are attending the programme at that moment. To evaluate some of the aspects it was considered interesting to divide the opinion of the ones working in a company (40 students) and the ones working in one of the lines of research of the university (21 students) and, on the other hand, also to know if the work experience was held in the 1st year (27 students) or 2nd year (34 students) of the master's degree. These students represent over the 50 % of the entire number of students.

The company is another key element when it comes to the CWSL programme. In fact, students are the future employees and they must fulfil the needs of the companies. In order to evaluate the satisfaction of the companies they were requested to fill in a questionnaire about technical and non-technical skills of the students.

Finally, the academic results have been analysed to get an overall view to compare the students in standard modality to those who are in the CWSL programme (*Figure 3*).

5 Results and discussion

5.1 Experience and opinion of students in CWSL programme

The survey was mainly focused on the skills developed during the work experience, as a complement to the studies. All the topics were very positively valued by the students, with a punctuation of over 3.8 points out of 5. We could remark that the highest punctuations were given to time management and autonomous learning as the most developed skills. This fact highlights that combining work and studying makes the students optimise how they make the most of their own time and get the best benefit from their time oriented to learning. On the other hand, the lowest punctuations were related to applying theory to practice. This could be attributed to the perception of the students of the lack of connection between the theories at university and the practice in the company.

Additionally, it is interesting to check the differences of the answers according to whether the working practice takes place in a company or at the university. All the facts had a higher punctuation in the case of the students at the university, except for the perception of their preparation for the work market. Students who are currently in a company feel they are more trained. Moreover, they specifically remarked that their job helped them get to know the organisation of an industrial company, the high connection among departments and the inter-company relations.

All these results can be observed in Figure 5.

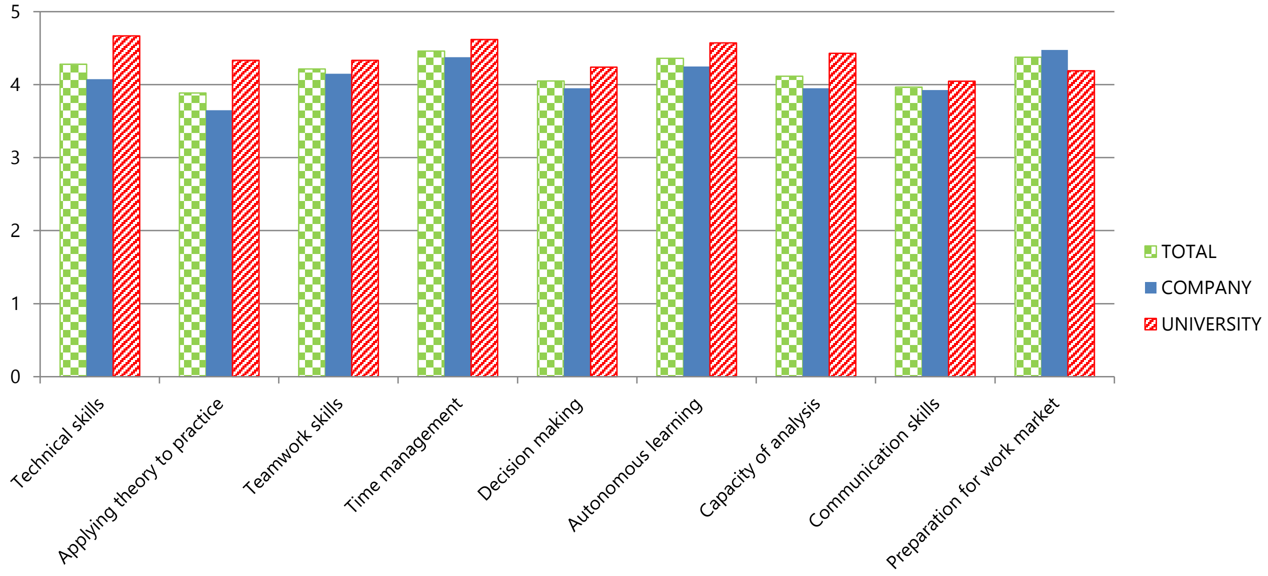

Figure 5: Results of the students' assessment of the developed skills in CWSL programme

The survey also focused special interest on whether the job developed by the students was oriented to research or not. The 100 % of the ones working at the university considered their job as research, which is aligned with the interests of the institution, but the 33 % of the in-company students also considered it so. This is a very positively valued fact, which makes a total of 56 % of the students working oriented to research.

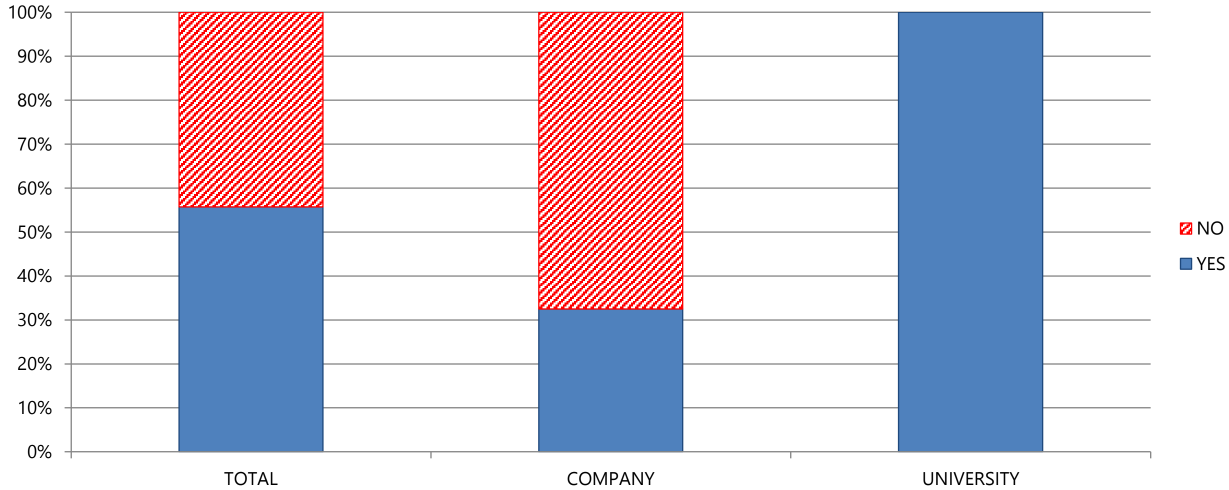

Figure 6: Rate of students who are researching in their CWSL experience, both in company and at university

When asked to describe their experience, most of the students pointed out they felt their job is highly valued among their workmates, and specially remarked positively the working experience in real situations, the improvement of their knowledge and the development of autonomous learning and maturing. Thus, the overall assessment of how the students value the programme is of 8.3 points out of 10 (8.2 for the in-company students and 8.7 for the ones at university). All the students ensured that they would encourage new students to join the CWSL programme, which represents a great result in the satisfaction of the students while, at the same time, showing improvement in several skills.

5.2 Students' assessment by the company´s supervisor

Figure 7 shows the results of the questionnaire answered by the supervisors of the students who are in companies as well as at the university. In general, students obtained good marks, over 8 points out of 10, in all fields. Therefore, this finding suggests that companies are satisfied with the students that are studying at Mondragon Unibertsitatea and with their work and involvement in the company.

Students from the 2nd year of the Industrial Engineering Master's Degree obtained better results in this questionnaire than students from the 1st year. This observation is logical as: i) second year students had studied more subjects at the university than first year students, and consequently their knowledge in the engineering field is wider and ii) they were working for a longer period of time at the company and thus, they were more trained in the workplace.

Technical skills were positively evaluated by the supervisors of the companies as can be seen in Figure 7. Interestingly, the learning capacity was even better evaluated. This implies that students are ready to keep on learning through their professional career. It should be mentioned that the active learning methodologies employed at Mondragon Unibertsitatea can help to educate autonomous students, which could be corroborated with these results.

Students involved in the CWSL programme are responsible, motivated, well adapted to work, good at managing their daily tasks and show a high personal implication at the company (see Figure 7). By contrast, the creativity and initiative of students did not obtain such a good evaluation, although it was improved during the second year of the trainee. This fact highlights that companies are demanding for more creative engineers. The creative skills of students could be improved by: i) including in the programme of the master's degree challenging activities focused on creativity and ii) encouraging students for that purpose at the company, especially at the beginning of the trainee.

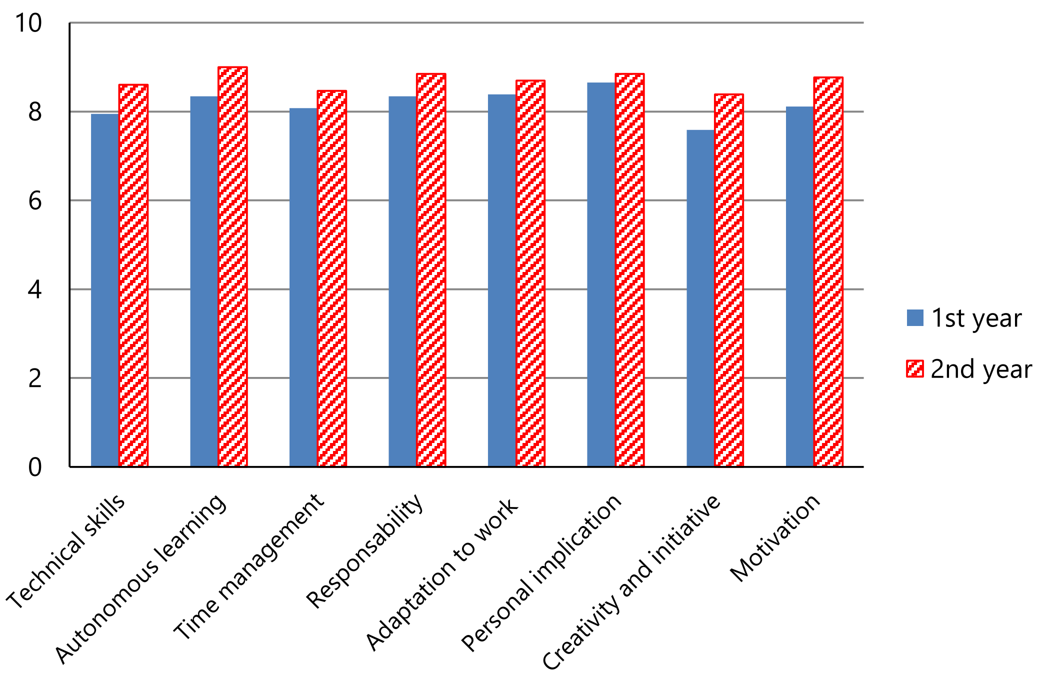

Figure 7: Evaluation of the technical and non-technical skills of the students carried out by the company

5.3 Academic results

Having analysed the students' final academic results and their position in the chart we can conclude that the ones who have combined work and studying got higher marks. In average the students that belong to CWSL programme have a 4 % more in their marks and summing the improvement from the first to the second semester their position in the ranking improved 87 positions (in a 84 student sampling). Furthermore, they also have been training professional skills by working part-time involved in a real industrial environment.

6 Conclusions

The main conclusions are the following:

- Students who combine work and studies improve both in technical and non-technical skills, and also in academic results.
- They are highly valued among their supervisors and workmates, and they show a high personal implication in the company.
- According to the previous facts, it is considered that a higher support from public institutions would be necessary, at all levels of education, to encourage blended work and studying experiences as a part of the curricula, connected to the *Triple Helix* model. Thus, the connection among companies, government and universities could be the key for the creation of new knowledge and innovative activities for the development of a country.

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Problem Based Teaching vs Problem Based Learning with CES EduPack

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Abstract

CES EduPack is software for materials-related education in science, engineering and design, mostly at the undergraduate level. It is one of the first and most successful examples of how to use computers specifically to facilitate teaching and learning, at Cambridge University (UK), starting more than 20 years ago. In this paper, we describe how this software is used to support teaching at two different levels in a project context. Firstly, we focus on the use as a student resource for what we call Problem Based Teaching (PBT), in courses that may partly or entirely have a project component. The features designed to facilitate self-directed and collaborative learning by students are described and examples from two Mechanical Engineering programs are given. Secondly, we describe how the software can be used as a resource for more in-depth project based learning that approaches Problem-Based Learning (PBL). A five-step methodology to evaluate Sustainable Development and provide a general platform for student learning on Sustainability is presented, with an example of a course project. These perspectives are investigated both from the Educator's perspective and from the students', where results from course evaluations are given. It is concluded that CES EduPack is an appreciated resource that promotes student-centered learning along the spectrum ranging from PBT to PBL.

Keywords: project based; materials; engineering education; PBL.

1 Introduction and Background

Problem Based Learning (PBL) has received substantial attention as a means to acquire complex, professional skills in higher education. This approach was originally developed and tested in the area of medicine (Neville, 2009) but has since evolved into other fields and even into pre-university education (Barrows, 1996). Engineering, in particular, is associated with problem-solving and a substantial part of most Engineering programs is dedicated to solving structured standard problems within their disciplines. This has the benefit of helping students to develop the necessary knowledge and skills, as well as providing a pathway to a common culture and language for their respective profession. However, this is not what is meant by problem based learning, which should rather be ill-structured and allow for free inquiry (Boud & Feletti, 1997). We call the classic engineering approach Problem Based Teaching (PBT), referring to the educator's perspective. The PBT approach without project components can be taken as a reference and starting point for further discussion on how to bring engineering courses nearer to full PBL. The idea of a diverse spectrum towards pure PBL has been critically discussed before (Hung, 2011) and one should be aware of risks and limitations.

One basic definition of PBL that can be used is by Barrows (1996), which lists 6 points, in brief: 1 Student centered learning, 2 Learning is done in small groups, 3 Facilitators or Tutors guide the students rather than teach, 4 A problem forms the basis for the organized focus of the group, 5 The problem is a vehicle for the development of problem solving skills, and 6 New knowledge is obtained through Self-Directed Learning (SDL). It could be argued that, for example: Assessment requirements, Tutor training and real world relevance should be added to this list (Savery, 2006).

1.1 Problem-based teaching

In order to make problem-solving more realistic (and therefore more relevant) and to promote the acquisition of general skills (again, relevant for an employer), project or case components can be added to educational programs. These are usually carried-out in small groups and sometimes with real-life problems to work on. Courses containing projects share important characteristics with PBL, such as self-directed learning and collaboration with a shared goal (project) (Savery, 2006). However, despite instructional strategies that promote active learning and engage learners in analysis and higher-order thinking, these tend to diminish the learner's role in setting goals and outcomes for the problem (Savery, 2006). Expected outcomes are normally set and assessed within the framework of the curriculum, whereas in the real world and in more "authentic" PBL it is recognized that the ability to both define the problem and develop a solution is important (Savery, 2006). Full PBL also require extensive preparation and appropriate training of the educators for this purpose, which is not always undertaken in traditional project-based courses for engineering. If a distinction between courses with significant components of projects and fully project-based courses is made, the latter is considered closer to the PBL philosophy.

1.2 Problem-based learning

To develop the learning process in engineering courses, a constructivist approach to instruction can be taken by the educator. This role is to guide and challenge the learning process rather than strictly providing knowledge (Hmelo-Silver, 2006). Inquiry-based learning and PBL are very similar in this respect. Both are grounded in the philosophy of Dewey, who believed that education begins with the curiosity of the learner (Savery, 2006). The main difference between Inquiry-based learning and PBL is the role of the tutor (scaffold). In PBL, the tutor supports the process but does not provide information directly related to the problem – this is the responsibility of the learners. In Inquiry-based approaches the tutor can participate and provide information (Savery, 2006).

In this paper, we describe how CES EduPack, a widely used resource for materials-related teaching, can be used to promote student-centered learning along the spectrum ranging from PBT to PBL (see Figure 1).

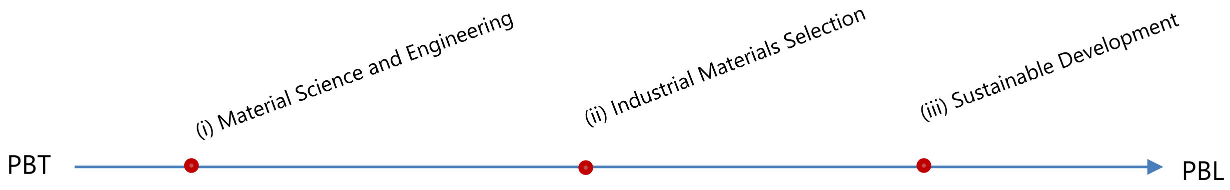


Figure 1: Schematic and highly qualitative illustration of the examples of CES EduPack use discussed in this Paper.

Three examples are described: (i) an introductory Materials Science and Engineering course for undergraduate Mechanical Engineering students without project components, (ii) an Industrial Materials Selection course within a Master's program in Mechanical Engineering, with a significant project component and (iii) a Sustainable Development module implementing an Inquiry-based methodology.

2 CES EduPack

In the examples given for PBT, we consider the Standard edition of CES EduPack, which was originally developed at the Engineering Department of Cambridge University (UK). CES EduPack, henceforth referred to as *the software*, is specifically developed for education, but is also part of a set of tools used for materials-related applications in industry and research; Granta MI and CES Selector (www.grantadesign.com). The links and similarities between the academic and industrial applications of the software ensure that students acquire relevant skills when using it as part of their degree or attending continuing education or professional training. Companies benefit equally from a work force well prepared for real-world problems.

The visual platform for material properties, the comprehensive databases with eco- and durability properties, manufacturing process data with a built-in cost model and the Eco Audit tool for a lifecycle perspective all lend themselves to collaborative multi-disciplinary project work. For these reasons, it has been suggested that the software would be beneficial for, *e.g.*, Global Engineering in a product development context (Fredriksson, 2014a). In Mechanical Engineering, it provides bridges between subjects with materials content, for instance, in courses on Materials Selection, Manufacturing, Product Development or Design.

At the heart of the software is the interactive visualization of material-, process- and environmental properties in charts which are used to facilitate both communication and understanding in the educational context. In Figure 2 (left), a typical Property Chart of *Stiffness vs Density* is displayed, showing the relationships between material types (metals, polymers etc.) and variations within each type. The dashed guidelines illustrate M*aterial Indices* that are used in advanced materials selection for specific applications.

For process selection, there is a library of data records containing descriptive images of hundreds of processes and a simple built in model for estimating production cost relating to different batch sizes and other factors, see Figure 2 (right). These data link to applicable materials and other parts of the database, such as possible shapes, to make selection and decision-making more realistic and multi-disciplinary.

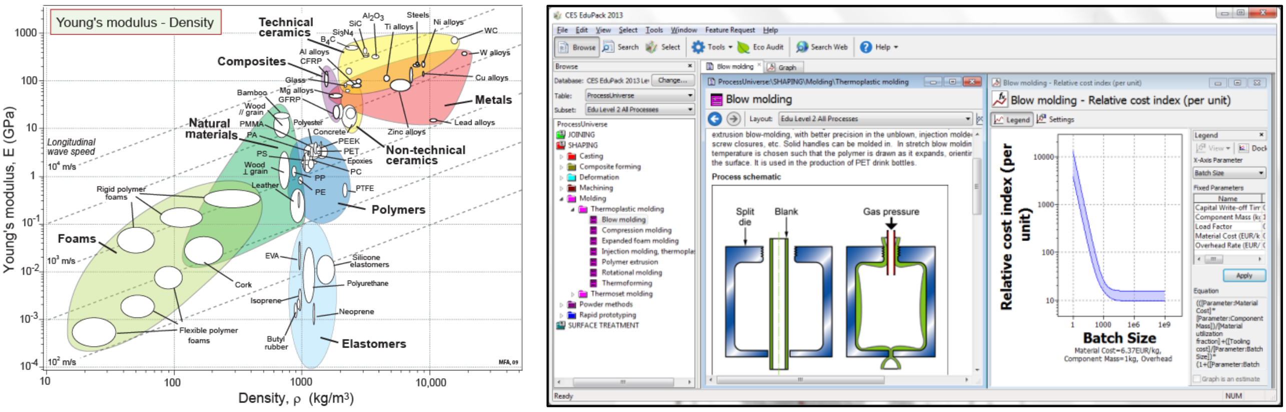


Figure 2: Material Property Chart visualising relationships within and between material types and facilitating materials selection (left) and example of a Process data record with the Relative Cost Index diagram from the built-in cost model.

The standard edition of the database has three "Levels" – it contains nearly 4000 materials, including metal alloys, polymer blends, hybrids and composites, as well as some 240 manufacturing processes, which enables realistic projects to be carried out. Approximate cost information and Eco properties, such as carbon footprint and water usage of the material are included to facilitate comparisons and qualitative discussions in classrooms and around product development projects. To promote self-learning, *Science Notes*, which are interactive *on-demand* features are available for every property included in the database. These give definitions and background to properties. In addition to Science Notes, there are also generic (folder level) records that give supporting information on the contents of the data record folders. An example for *Wrought aluminum alloys* is shown in Figure 3, together with a Science Note on the property *Abundance in Earth's crust and oceans*.

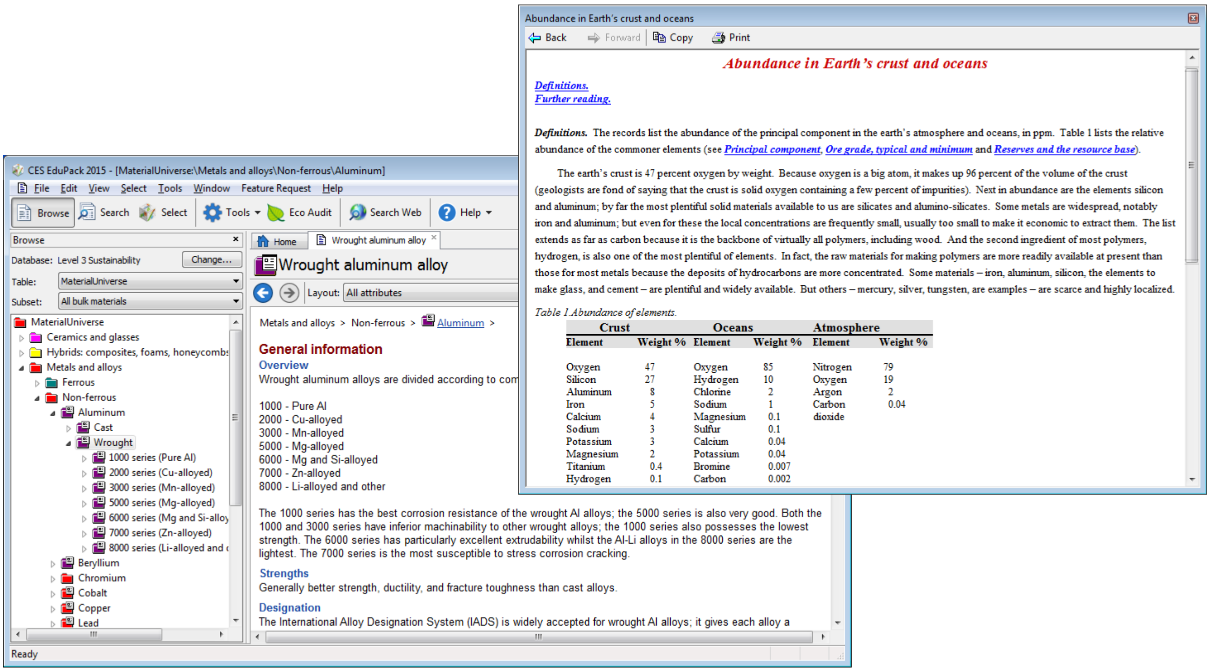


Figure 3. Examples of a generic record for Wrought aluminum alloys (left) and a Science Note (right).

Another important feature is the built-in *Eco Audit* tool which is used to analyze carbon footprints and embodied energies, during the design process. This is particularly useful to cover *Life-Cycle Engineering* or similar course content. The Eco Audit is a simplified Life-Cycle Inventory that specifies the energy or CO_2-emissions for the phases: *Material*, *Manufacture*, *Use* and *Disposal* as well as for all *Transport* during the product life-cycle. The result is based on a supplied *Bill of Materials* (BOM), *Embodied energies* for the included materials and the nature of the energy mix used. Data for the latter two are contained within the database.

In Figure 4, a Bar Chart for the Eco Audit of a new PET bottle of mineral water transported and refrigerated before consumption is shown. In the same chart, supplementary *what-if* Eco Audits are shown for alternative scenarios using a glass bottle or a bottle from recycled PET instead. The EoL bar represents the potential *End-of-Life* benefits, depending on recycling options. The recycled PET bottle has the lowest environmental impact.

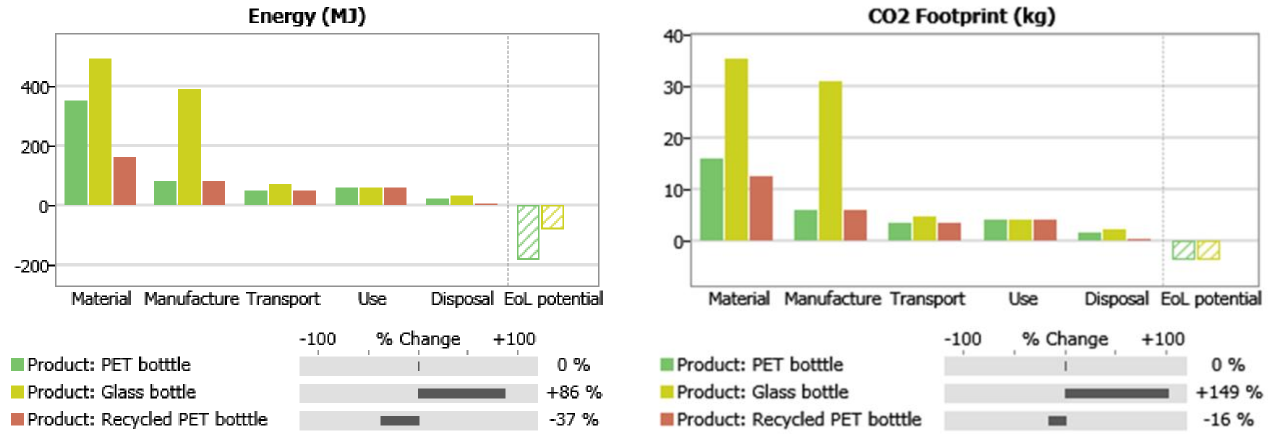


Figure 4: Eco Audit Chart visualising the embodied energy and carbon footprint for three different mineral water bottles.

The software is built around databases that contain information on properties useful to several areas of Engineering. Extensive built-in support for the students, such as the *on-demand* Science Notes, promotes self-directed learning and links, *e.g.*, to producers of materials, enables realistic assignments or projects to be carried out. We have studied its use in three different course contexts to investigate how useful it is.

3 Examples in Problem Based Teaching

Project-based courses represent an approach taken by engineering educators to increase the elements of realism, compared to traditional, textbook and lecture-based teaching. This, hopefully provides the conditions for going beyond the knowledge and understanding associated with textbook learning. As a starting point, the first example is a traditional PBT course without a project component. However, the software complements the textbook and assignments as well as computer labs are used to enhance the course.

3.1 Non-project based course

In the first example, we report how the software has been utilized throughout a programme of Mechanical Engineering in University West (Sweden). Here, a first (freshman) year introductory class of Materials Science and Engineering is described and student responses collected via course evaluations are shown for three years 2010-2012.

Students enrolled in eligible Departments or Universities can have access to the software on their individual laptops or at home during their course work, which enables them to benefit from it also in online or distance learning programs. Since this software can be made available individually to students and since it is backed up by several textbooks and teaching resources (Ashby, 2011, 2014, www.teachingresources.grantadesign.com), it appears suitable for *flipped classroom* teaching or assignments in student groups in *traditional* or *hybrid* teaching approaches. Both these methods were used to some extent in the course.

The software was initially introduced to students at University West in this basic course on Materials Science and Engineering. The progressive use throughout the Mechanical Engineering programme is shown in Figure 5. To prepare students to use the software as an independent resource throughout their education, there is an introductory class and demonstrations at the start of the course. This is followed by assignments, where the software is used in small groups. Towards the end of the course, there is an individual computer lab focused on materials selection using the software and the software is also extensively used in the treatment of environmental and sustainability aspects of engineering materials. At the final exam, there is a section dedicated to *materials selection and the environment*, where property diagrams (*Ashby charts*) are used as part of the assessment of acquired skills. Although the course is very "applied", it has no project component.

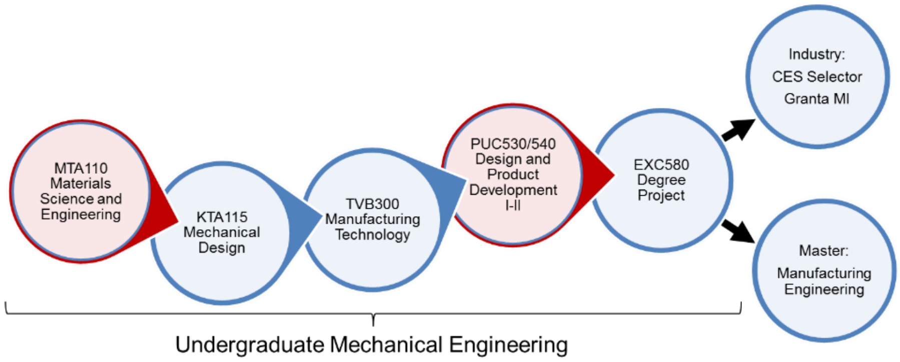


Figure 5: Progression of Courses with CES EduPack as a resource. The first and fourth (in red) use the software extensively.

The result of a course evaluation by students of the Materials Science and Engineering course for three consecutive years is given in Figure 6, The response frequency was about 90% as the evaluation was done at the end of a class (n=36-49). These results have been previously published and discussed (Fredriksson, 2014b).

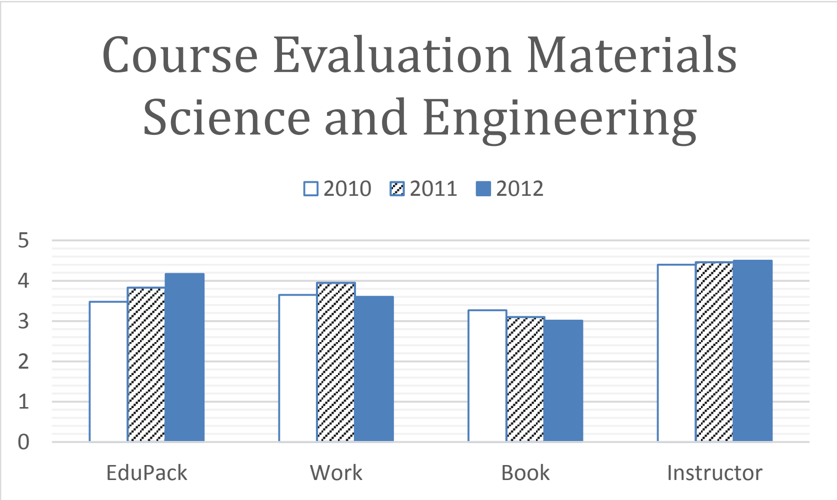


Figure 6: The result of consecutive course evaluations of Materials Science and Engineering course (5=very good).

The student evaluations show that the software is a valued component of this course. The results of the anonymous survey showed that the average response to the question: *How good did you think that the materials selection software (CES EduPack) was?* increased from 3.5 to 4.2 (first bar) over the three years. This may reflect an increasing skill of the Instructor, as the software was only introduced in 2009. The overall performance of the Instructor was rated evenly around 4.5 every year (fourth bar) and the self-assessed student work effort (second bar) did not show a trend over these years. The appreciation of the Swedish course textbook seemed to decrease slightly over the period (third bar) while the software gained, possibly reflecting an increasing trend of self-directed learning using the software. Further details of this study is reported elsewhere (Fredriksson, 2014b). The recorded qualitative benefits of using CES EduPack in a subsequent, fully project-based, course on Design and Product Development (PUC530/540 in Figure 4) are also described there.

3.2 Partially project-based course

In the second example, we describe and evaluate how third year mechanical engineering students use the CES EduPack in a materials selection course (TMKM 14) at Linköping University, Sweden. Prior to the course, the students have taken a basic traditional course in Materials Science and one aim of the materials selection course is for students to use their prior knowledge to solve material selection problems. Since the topic and scope of the course is Industrial Materials Selection, the software is used as a tool not only to carry out smaller material selection exercises but also during a larger project with the aim of acquiring real-world skills. A study was conducted in order to gain a deeper understanding on how the students experience the software in order to improve the learning process in the course.

The student reactions were researched in two ways: firstly, a quantitative printed survey in which all the students (roughly 100) were asked to rate their opinions regarding CES EduPack and its usefulness, and secondly, a focus group containing five randomly selected students whose reactions to specific functionalities in the software were explored more qualitatively. In the survey, the majority of the students found the software to be "Very good" when performing both small and large material selection tasks, see Figure 6. The question was: *What is your general opinion about the materials selection software CES EduPack?* Nobody ticked "Not so good".

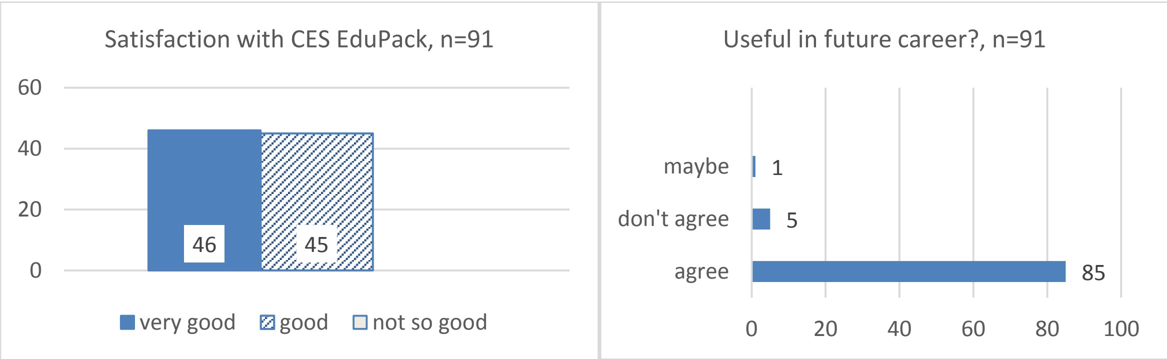


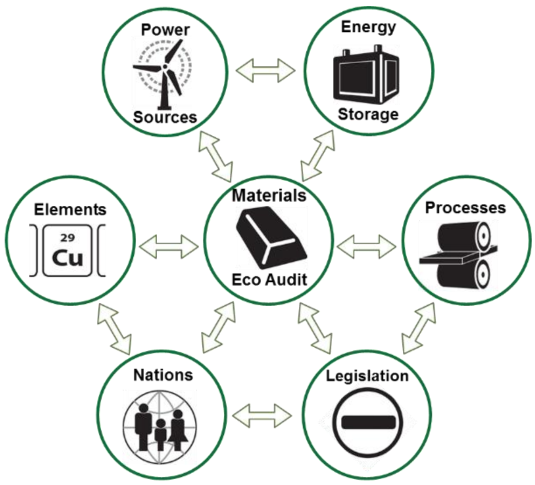
Figure 7: Outcomes from course evaluation for general opinion (left) and future utility (right) of CES EduPack

The survey also indicated that students expected to be able to use materials information software, such as the CES EduPack in their future roles as Engineers. The question was: *Do you think that this course has given you good insights into materials selection and could you perform materials selection using material databases, such as the CES EduPack, as tools in your future as Engineer*? 85 out of 91 answered yes to this question.

The survey shows that the software was highly appreciated in its applied context. The style of the course is student-centered but the role of the educator was typical of *Curriculum-based* teaching, rather than *coaching*. The learning is only self-directed to a small extent. In the focus group, several aspects were discussed. For example, both the material and the process data were found to be easy to use, given the students prior level of knowledge. Thus, it is clear that the software is able to contribute to the learning process of students. However, they found some concepts difficult to implement, for example material indices through the gradient line selection. The discussion with the focus group suggests that it is the theory which is the learning obstacle rather than the software itself. It is proposed that learning can be further enhanced by addressing such issues when discussing the material selection methodology during the course.

4 Examples in Problem Based Learning

The last example of implementation of the software is the combination of a 5-step methodology for analysis of Sustainable Development (Ashby, 2015) and an extension of the Standard Edition of the software. The problem consists of assessing whether a proposed materials-related technology can be considered a Sustainable Development. The topics of Sustainability and Sustainable Development are well suited to PBL, since they are open-ended and complex multi-disciplinary issues. The software has been developed to work as a resource for such kind of topics. The Sustainability database, which is an enhancement of Level 3, contains data enabling analysis of articulations (proposals) of Sustainable Development, in the context of technology. The structure of the database, including links between data tables, is shown in Figure 8, below.



Linked Data Tables:

MaterialUniverse

ProcessUniverse

Legislation and Regulations

Power Systems (Storage, Sources)

Nations of the World

Elements (Reserves, Criticality etc.)

Manufacturing Processes Eco data

Figure 8. Structure of the sustainability database for CES EduPack and names of data tables.

As can be seen from the content, the data covers several areas relevant to sustainability, providing support for self-directed learning. The Sustainability database has proved powerful as a resource of the fact-finding step in this process. If the methodology, described by Ashby (2015), is implemented in small student groups (see Figure 9) with Tutors aligned with PBL, the conditions for full PBL are present. *Assessment rubrics* and *Learning portfolios* are suggested for assessment of learning. The students can formulate their own articulation but a number of cases exist (intr-oduction of electric cars, biopolymers etc.) and can be used for inspiration. Several versions of the method, ranging from workshops to Master's courses in Sustainable Design have been tried out successfully. If the objectives of PBL are achieved or not depends, of course, crucially on how the project is implemented. For details on the implementation in a full course, we refer to a more thorough description elsewhere (Ashby, 2015). Here, we only summarize the qualitative outcome of one case considered as typical.

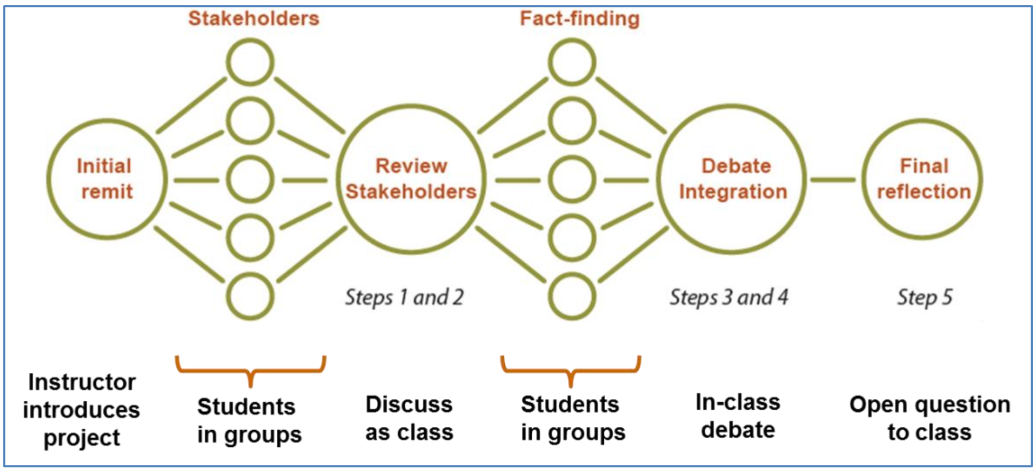


Figure 9. Structure of the suggested 5-step methodology for assessing Sustainable Developments within PBL.

The feed-back from a Masters course at the Technical University of Catalonia (UPC) include (Ashby, 2015):

- Consistent, holistic, very useful approach. The five step method is simple and concrete – a useful framework for tackling complex problems
- Students appreciate the methodology. It provides a structure that allows a systematic approach while remaining holistic and recognizing the inherent complexity of sustainability issues.

5 Conclusions

We conclude that CES EduPack is an appreciated resource that promotes student-centered learning along the spectrum ranging from traditional Problem-Based Engineering courses, which we have called PBT, to more in-depth Problem-Based Learning situations, PBL. For PBT, we have described one course without projects (example i) and one with a considerable project component (example ii). These are contrasted with a more complete PBL course (example iii) in Table 1, below. In these examples, the main difference is the role of the educator and the degree of self-directed learning. The main advantage of having a project component in the course, in this PBL context, is the collaborative aspects from learning in smaller groups. As mentioned in the introduction, more recent criteria for PBL include Assessment requirements, Tutor training and Real World relevance (Savery, 2006), which makes it harder to assess the type of learning for a general case.

Table 1: Summary of criteria for PBL assessed by the Author for the courses representing PBT (i-ii) and PBL (iii)

Course	1 Student-centered learning	2 Learning in small student groups	3 Tutors/ facilitators guide rather than teach	4 Organized focus on a problem	5 Problem-solving skills	6 Self-directed learning
(i) Materials Science and Engineering	**Yes**	**No**	**No**	**No**	**Yes**	**No**
(ii) Material Selection	**Yes**	**Yes**	**No**	**Yes**	**Yes**	**No**
(iii) Sustainable Development	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

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Supporting students in practical design assignments using design-based learning as an instructional approach

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Abstract

This paper aims at presenting the experience of the Power Conversion project in teaching students to design a proof-of-principle contactless energy transfer system for the charging of electrical vehicles. In this second year electrical engineering project students are to gather and apply electrical engineering knowledge to design and test a system that can work with power level and operates independent from an electricity grid. In doing so, students are to construct electric circuits with preliminary defined component values with the possibility of using as well certain assumptions. The added value in this project is the instructional methodology used, i.e. *design-based learning*, to have students learn aspects of an electronic system such as the implementation of the speed controlled and the use of the wind turbine operation while working on *open-ended* assignments. In this project students are to act as professional engineers in teams and design iteratively a contactless power delivery system. Therefore, they play the role of production manager, electrical circuits' designer or electrical engineer. The support of the students' learning encounters have a double structure: on the one hand, students are to learn how to apply the knowledge and theoretical insights in their professional role as electrical engineers. Moreover, the technical feedback the students receive by experts is embedded in *authentic* tasks such as that the modelling and simulating in an industry scenario. On the other hand, students are guided by a project leader, i.e. tutor, who provides feedback on not only the methodology regarding the process, but also on the self-development of the student. The latter task of the tutor is framed within the formative assessment approach for product design. The assessment instrument used, among others, is the *rubric*. Rubrics are based on the quality criteria of the final system, e.g. Power (W), Efficiency, Maximum Power Point Tracking algorithm (MPPT), Load detection and Ggrade demonstration.

Keywords: engineering education; project approaches; design-based learning.

1 Introduction

Although design-based learning has been the educational method for over the past 17 years at the Eindhoven University of Technology in the Netherlands (Wijnen, 2000), this approach has been adapted to serve the purposes of the Power Conversion project. In this project students are to act as professional engineers in teams and design iteratively a contactless power delivery system by modeling and constructing electric circuits with preliminary defined component values with the possibility of using as well certain assumptions (Atman et al. 2007; Dym, et al. 2005).

The rationale behind this is to have students to validate the model and initial assumptions by measurements and simulations (Lawson & Dorst, 2009). The instructional approach in this course is design based learning (DBL) (Gómez Puente, van Eijck, & Jochems, 2014). In DBL projects, engineering students are to gather and apply knowledge while working on the design of artefacts, systems and innovative solutions in project settings. The characteristics of the projects, the design elements, and the role of the teacher are pivotal components within the DBL educational approach that foster students' design problem-solving process (Mehalik & Schunn, 2006; Sheppard et al. 2008).

2 Design-based learning in engineering education

Design-based learning (DBL) is an educational approach that has been mostly used in the context of secondary education to teach science curriculum (Apedoe et al. 2008). DBL has served to help students acquire problem-solving and analytical skills common to science classes while they work on design assignments (Kolodner, 2002), and Design-based Science (Fortus et al. 2004).

In the context of higher education, however, DBL is rooted in the educational principles of problem-based learning (PBL) (De Graaff & Kolmos, 2003) as a way to develop inquiry skills and integrate theoretical knowledge by solving ill-defined problems (Mehalik, Doppelt, & Schunn, 2008). Some specific elements of the approach emphasise the planning process embedded in engineering assignments while applying knowledge of the specific engineering domain through student involvement in the design activities of artefacts, systems or solutions. In the context of engineering education, we define design-based learning as an educational approach with five characteristics: the project features (open-ended, authentic, hands-on and multidisciplinary), the role of the teacher in providing feedback, the assessment (formative and summative), the social context; and the design elements (Gómez Puente, van Eijck, & Jochems, 2014).

When conducting problem solving in design assignments, students go through the engineering design process by identifying the design problem, conducting research on the assignment in order to develop solutions which are most suitable to construct the first prototype and test. Finally, and based on results, students make adjustments in the design in an iterative process.

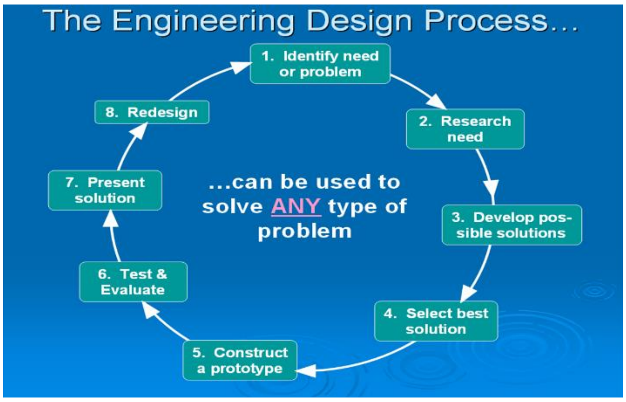

Figure 1: Students' (implicit) approach in design activities (retrieved from http://www.cs.uml.edu/teams-academy/index.php/ATDF2008/EDP%3E, February, 2015)

2.1 Methodology

The Power Conversion project has gone through different iterations in its design in the last three academic years. We compared the results of the project in three consecutive years following some differences in the instructional design. In 2011/2012 the project approach consisted of hands-on assignment to model and design a prototype, and test requesting one iteration only. The project description provided general specifications including the architecture of the solution and very few intermediate deliverables. In addition, the project was a practical (but-scaled) real-life industrial problem; however no client or user was involved. The redesign of the Power Conversion project in 2012/2013 focused however on a more open-ended assignment in which the architecture of the system was not given and only minimal specifications were included. Although the project was open, the supervision on students' interim products increased in order to assure a proper follow up of achievements (Gómez Puente, van Eijck, & Jochems, 2014). Moreover, to make this project more authentic the role of the teacher turned to be that of a client requesting frequent presentations of product design. Finally, despite the fact that the hands-on character of the project didn't change as students were requested to model, design a prototype and test it, the iterative approach was strongly encouraged. The redesign of the project in 2013/2014 was caused by a curriculum change in which the total number of hours for the project increased from 84 to 112, but the project was given in eight weeks instead of 14 weeks.

3 The supervision

Following Hattie & Timperley (2007) the supervision strategy in this project to support students in designing is based on providing feedback on three levels: feedback on the task, on the process (both on methodology and teamwork), and finally on the self-development of the student. In enhancing students' tasks it is also essential that students get feedback but also forward and feed-up on the progress in designing devices and systems. The actions of the supervisors (both teachers and tutors) during this process are, for instance, to challenge students by asking questions; to stimulate the process of consultation and questioning to help arrive to fully develop specifications in order for the students to realize whether they need more information and improve own design; to give just-in-time teaching strategy in the form of suggestions to carry out missing tasks; to encourage the evaluation of the process and self-reflection; or just by providing feedback upon mid-term deliverables. Moreover, in giving feedback the supervisors make use of rubrics as a tool for learning. In Table 1 we present an example of the rubrics employed to enhance students' learning.

Table 1. Example of the rubric for the Power Conversion project

Criterion	Poor	Marginal	Average	Good	Excellent
Understanding own specialization	Shows no understanding of own research topic.	Shows only marginal understanding of own research topic.	Has a reasonable understanding of own research topic.	Shows a good understanding of both the overall system and own research topic.	Has understood both the overall system and own research topic completely, which has led to a good design.
Understanding overall system	Shows no understanding of the overall system.	Shows only marginal understanding of the overall system.	Has a reasonable understanding of the overall system.		
Research skills **(Use of resources)**	No resources have been used, or have been wrongly used.	Only a few resources have been used (manual has been read and used).	Most resources (manual, literature research, expert) have been used, but not consistently.	All resources have been used, able to ask questions and to find relative literature.	Able to solve a problem efficient by using resources (literature, experts).
Dedication **(motivation / initiative)**	Let's others do the work and a negative attitude which affects other group members.	Negative attitude towards the project team. Tends to watch others, gets involved only when necessary.	Completes his/her tasks. Neutral attitude towards the project and the team.	Positive attitude towards the project and the team. Gets involved in the project.	Takes initiative, very involved in the project. Concerned with getting the job done.
Communication within the group **(technical aspects about the project)**	Communication skills ineffective. Does hardly communicate with other group members.	Communication skills ineffective. Does marginal communicate with other group members.	Communicates with other group members about own research topic.	Communicates with other group members about own research topic and total system (Asks questions).	Communicates effectively with other group members about own research topic and the total system.
Dealing with feedback	Feedback is not accepted by the individual at all.	Feedback is accepted but ignored by the individual.	Feedback is accepted by the individual and an attempt is made to account for it.	Individual shows serious interest in understanding the feedback and accounting for it.	Feedback is accepted by the individual and is optimally used.
Quality of the technical work done	Work must be redone by other to meet standards.	Work must be redone or repaired to meet standards.	Quality of the work is acceptable.	Work is of high quality. A producer.	Work is of exceptional quality.
Planning	No plan is given.	Only a very schematic plan is given. Planning is unrealistic.	A schematic plan is given, with some interlinking to other activities. Planning is	A detailed plan is given, interlinking to other activities. Planning seems realistic.	A detailed plan is given, with interlinking to other activities. Planning seems realistic and

The supervision in this project is not a stand-alone action. During the redesign of the project activities, the scenario followed a number of transformations. In the first edition of this project, the faculty staff, the experts in the different electrical engineering fields, provided content input along the development process of the design. Later, the project was adjusted in such a way that the responsible teacher took an authentic role as he was the client from a company who in the form of intermediate contact meetings was providing input in the design process.

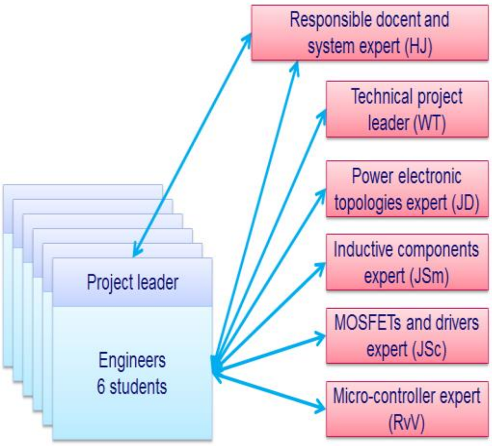

Figure 2. Project set up in 2012-2013

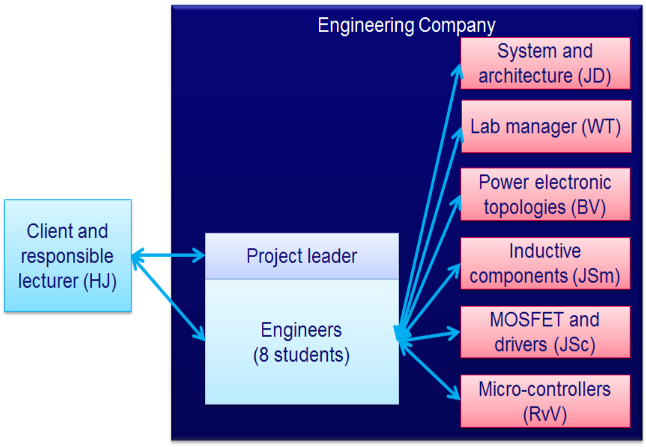

Figure 3. Project set up in 2013-2014

4 Findings and results

In order to gain an overview of achievements, we compared the quality of the students' products of the different groups along three consecutive years. In doing so, we compared students' products concerning the following criteria: the transferred power (W) of the system, the efficiency, the implementation of a Maximum Power Point Tracking algorithm (MPPT), the load detection, the grade in the final demonstration. Tables 2, 3, 4 and 5 show the differences among students' groups along the years regarding the criteria to judge the quality of the designed systems.

Table 2. Overview students' groups results in 2011-2012

	2011-2012					
Group	1	2	3	4	5	6
Power (W)	129	187.5	190	100	FAIL	145.5
Efficiency (%)	58%	78%	73%	79%	FAIL	62%
MPPT	no	no	no	no	no	no
Load detection	no	no	no	no	no	no
Grade demonstration	6.5	8	8	8	6	7

As we can appreciate in Table 2. students have difficulties in showing how the implementation of the algorithm works regarding the Maximum Power Point Tracking. We find the same difficulties regarding the load detection. The same difficulties are encountered with respect to the Load detection. The Efficiency of the system however shows normal to high levels except in one group; as well as the Power system except in one group.

Table 3. Overview students' groups results in 2012-2013

	2012-2013						
Group	1	2	3	4	5	6	7
Power (W)	94	170	101	100	218	175	FAIL
Efficiency (%)	73%	87%	77%	77%	78%	75%	FAIL
MPPT	yes	partly	no	no	yes	yes	no
Load detection	yes	yes	no	no	no	yes	no
Grade demonstration	9	6	7	6.5	7.5	8.5	5.5

Comparing the results given in Table 3. with the previous one, we observe that both the implementation of the algorithm and the load detection works in most of the systems. The same of the variables remain within the normal ranges. Although it is difficult to identify the reasons that can explain the improvements in students' systems regarding MPPT and Load detection, we tend to think that the setup of the project in 2012-2013 consisting of an open-ended assignment in which the architecture of the system was not given has lead students to look for alternatives and test them in different iterations. Furthermore, the project leaders in their role as tutors have coached the students with the use of clear criteria and instruments, i.e. rubrics, in order to support the students in the implementation of the tasks (i.e. designs); the process (i.e. group work and methodology), and finally, in the self-development (own learning), (Hattie & Timperley, 2007).

Table 4. Overview students' groups results in 2014-2015

	2013-2014						
Group	1	2	3	4	5	6	7
Power (W)	100	190	104	199	174	115	64
Efficiency (%)	70%	66%	63%	71%	65%	73%	46%
MPPT	no	yes	yes	no	no	no	yes
Load detection	no	partly	yes	no	no	partly	partly
Grade demonstration	5.5	7.5	8	6	7.5	6.5	7.5

Observing the data given in Table 5., we perceive that in general terms the groups' outputs of the systems has not change drastically. Although the project was reduced in number of weeks (from 14 to 8 weeks), this has not caused apparently major impact in students' products. The main reason is, probably, that the iterative approach has been strongly encouraged and that the tutors has also focused in the supervision and coaching of the students' on products and deadlines. The milestones for the presentation of mid-term products may have also been a factor that has influenced that students implement the simulations and test, and accordingly, the iterations to finally produce a system.

Table 5. Overview of all students' groups with regards to the criteria on quality of systems

	2011-2012	2012-2013	2013-2014
Power (W)	150	143	135
Efficiency (%)	70%	78%	65%
MPPT	0%	43%	43%
Power tracking	0%	43%	29%

As we can appreciate, the quality of the students' products is most appreciated in the design in 2013/2014. Although we are careful in making statements we observe that the set-up of the project including the increase of number of hours. This increase was translated in intensive supervision as the project was carried out in 8 instead of in 14 weeks. The supervision has also created positive effects in the improvement in the power, efficiency, MPPT, load detection, grade demonstration and power of the system designed.

5 Conclusions

Design-based learning is a promising approach to have students to gather knowledge and apply it in design product and systems. Based on these experiences along the years, we observed that the influence of the project characteristics such as for instance open-ended in 2012/2013 has influenced students' design as the criteria Efficiency, MPPT, and Load detection show interesting differences. With regards to Power (W) however, results do not show dramatic changes along the years as the efficiency. A clear increase in system efficiency can be observed in 2012/2013, which reduced in 2013/2014 in which the students did not have sufficient time for system optimization due to the reduced period in which the project was conducted.

Furthermore, the role of the tutors have played a major role. As exposed earlier in this paper, both the role of the tutors in giving feedback, supervising and coaching students, as well as the development and improvement of the instruments to provide coaching have been decisive to influence the quality of the students' systems. In addition, the improvement over time in design performance is also a common by-product of the teachers in having better understanding of the problem after multiple iterations of the project.

Grounded on these experiences, we conclude that DBL is an educational approach that support students in gathering and applying knowledge while working on engineering problems that supports students in exploring different routes, experimenting and developing solutions in iterations (Lawson & Dorst, 2009). Despite these interesting results, other routes to improve students' design methodology are still to be investigated.

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IJCLEE/PAEE'2015 Full Papers Submissions (Portuguese)

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Reading, writing and speaking skills in Engineering from the perspective of Active Learning

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Abstract

When engineers start in the world of work, they initiate to interact and participate in different language practices involving reading, writing and speaking skills. These literacy practices are features in engineers' professional life. In this context, this study aims to understand the literacy practices that are part of the daily work of engineers and the implications of reading, writing and speaking skills in this work sphere. Therefore, we analyzed data from two different contexts: interviews with graduated engineers that work in their area in Brazil, these engineers had a traditional graduation, inserting themselves into the work world after graduation; interviews with graduating students of the MSc in Industrial Engineering and Management (MIEGI) of the University of Minho in Portugal, participants through the PBL (Project-Based Learning) of projects allocated within companies during the 7th semester of the graduate program, which favors the interaction between graduation and the professional world. The analyzes are anchored in the propositions of the Bakhtin Circle and in the understandings of New Literacy Studies. Data indicate that the engineer professional life inserts them in specific literacy practices. Reading, writing and oral expression are more fully developed when the graduation course is based in the theories of active learning as PBL, because students become part of a procedural work in building knowledge on these literacies. To participate in projects, which include activities in their daily work, engineering students take domain of specific literacies of their field. Therefore, the theories of active learning contribute to a more direct dialogue between the academic and professional training of the engineer concerning the participation in literacies events.

Keywords: literacies; language practices; engineering; active learning.

Leitura, escrita e oralidade nas Engenharias sob a ótica da Aprendizagem Ativa

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Resumo

Ao se inserirem no mundo do trabalho, os engenheiros passam a interagir e participar de diferentes práticas de linguagem, que envolvem leitura, escrita e oralidade. Essas práticas de letramento são características do fazer profissional de engenheiros. Neste contexto, o presente trabalho tem como objetivo compreender as práticas de letramento que integram o cotidiano profissional de engenheiros e as implicações da leitura, escrita e oralidade nessa esfera de trabalho. Para tanto, analisamos dados de dois contextos distintos, a saber: entrevistas com engenheiros formados e atuantes em sua área de formação no Brasil, os quais tiveram uma formação tradicional, inserindo-se no mundo do trabalho após a graduação; entrevistas com estudantes concluintes do Mestrado Integrado em Engenharia e Gestão Industrial (MIEGI) da Universidade do Minho, em Portugal, participantes, por meio do PBL (Project-Based Learning), de projetos alocados dentro de empresas durante o 7º semestre do curso de graduação, o que favorece a interação entre academia e mundo profissional. As análises dispostas nesta proposta estão ancoradas nas proposições do Círculo de Bakhtin e nas compreensões dos Novos Estudos do Letramento. Os dizeres dos sujeitos sinalizam que a atuação profissional do engenheiro o insere em práticas de letramento específicas. Ler, escrever e expressar-se oralmente são capacidades mais amplamente desenvolvidas quando o curso de formação está pautado nas teorias de aprendizagem ativa como o PBL, pois o acadêmico se insere em um trabalho processual de construção de conhecimento acerca desses letramentos. Ao participarem de projetos, os quais contemplam atividades do seu cotidiano profissional, os estudantes de engenharia se apropriam de letramentos específicos do seu campo de atuação. Dessa forma, as teorias de aprendizagem ativa contribuem para um diálogo mais direto entre a formação acadêmica e profissional do engenheiro no que tange à participação em eventos de letramentos.

Palavras-chave: letramentos; práticas de linguagem; engenharia; aprendizagem ativa.

1 Palavras Iniciais

No atual cenário globalizado, no qual há informações por todos os lados, cada vez mais participamos de diversificadas práticas de linguagem. De acordo com cada esfera de atuação social (Bakhtin, 2003), somos inseridos em diversas situações nas quais a linguagem assume diferentes funções. Nesse contexto, o presente artigo enfoca a forma como os sujeitos se apropriam das práticas de linguagem em um ramo bastante específico: a engenharia. Nesse sentido, o presente trabalho preconiza a interface academia e mundo profissional de engenheiros.

As discussões ora propostas estão vinculadas ao projeto maior denominado “Padrões e funcionamento de letramento acadêmico em cursos brasileiros e portugueses de graduação: o caso das engenharias”. O projeto vem sendo desenvolvido desde 2010 em uma parceria entre a Universidade Regional de Blumenau (Brasil) e a Universidade do Minho (Portugal). No universo desse projeto, são pesquisadas as práticas (Street, 2003) e eventos de letramento (Barton & Hamilton, 2000; Heath, 1982) que fazem parte da formação do profissional engenheiro. Pesquisam-se, ainda, os reflexos dessa formação no que tange às linguagens em uso no cotidiano profissional dos engenheiros (Franzen, Schlichting & Heinig, 2011; Schlichting & Heinig, 2012; Schlichting & Heinig, 2013; Fischer & Heinig, 2014).

Situado neste cenário mais amplo, o objetivo deste artigo é compreender as práticas de letramento que integram o cotidiano profissional de engenheiros e as implicações da leitura, escrita e oralidade nessa esfera de trabalho. Para tanto, recorremos a dados de dois contextos específicos, a saber: entrevistas com engenheiros atuantes em sua área de formação, os quais se graduaram em cursos baseados nas chamadas metodologias tradicionais de ensino, no Brasil; entrevistas com estudantes do sétimo semestre do Mestrado Integrado em Engenharia e Gestão Industrial (MIEGI), que participaram, durante sua formação, de projetos pautados nas teorias de aprendizagem ativa. No presente trabalho, analisamos dizeres de quatro sujeitos assim identificados: E01BR e E02BR, engenheiros civis formados no Brasil, E01PT e E02PT, alunos do quarto ano do Mestrado Integrado de Engenharia em Gestão Industrial de Portugal.

Os dados foram coletados por meio de entrevista semiestruturada, que segundo Bogdan e Biklen (1994) permitem que o entrevistador conduza a conversa, mas que o entrevistado esteja livre para desenvolver suas propostas. A pesquisa é de cunho qualitativo-interpretativista e está inserida na área da educação em diálogo com as engenharias, a fim de colaborar com o campo da educação em engenharia no que tange à compreensão de como são sistematizados os conhecimentos e fazeres sobre as linguagens em uso nas engenharias. Isso permite refletir sobre a construção de um diálogo acerca das atitudes responsivas de profissionais e currículos da área da educação em engenharia relativas às capacidades de leitura, escrita e oralidade e seus reflexos no mundo do trabalho em engenharia.

Para análise do *corpus*, optou-se pela perspectiva enunciativa (Bakhtin, 2003; 2006), na qual o analista considera, inicialmente, a palavra em sua superfície e nela pistas linguísticas que possibilitem a depreensão do sentido, considerando, o contexto em que a enunciação se realiza, isto é, o espaço-tempo dos dizeres e o auditório social a quem o dizer se dirige bem como a imagem que o locutor tem do referente (Heinig, 2011). O olhar analítico se dirigiu para as dimensões dos gêneros discursivos e para as funções sociais dos letramentos (Barton & Hamilton, 2000; Street, 2003; Dionísio, 2007).

Para este trabalho, a escolha desses distintos contextos de formação se deu porque oferecem duas compreensões diferentes da inserção no mundo profissional e em suas respectivas práticas de linguagem: enquanto o estudante que teve uma formação pautada na metodologia tradicional de ensino se insere no mundo do trabalho depois de formado; o contexto estudado, que se baseia nas metodologias ativas, insere o acadêmico em sua esfera de trabalho ainda durante a graduação, por meio dos projetos. Vale ressaltar que, ao traçar esse paralelo entre os contextos, não temos como objetivo comparar um e outro, mas sim compreender as diferenças entre eles e as suas implicações na inserção dos jovens engenheiros no que diz respeito à linguagem em uso em sua esfera profissional.

A construção histórica apresenta a engenharia como uma área essencialmente exata, ligada aos números, cálculos e tabelas. Atualmente, porém, a identidade do engenheiro tem se modificado a fim de atender às demandas sociais de uma sociedade essencialmente comunicativa (Booth, Villas-Boas & Catelli, 2008). As capacidades de leitura e escrita e a participação em práticas de letramento na engenharia deixaram de ser um diferencial para os profissionais e passaram a integrar o currículo de necessidades básicas para o desempenho da profissão. Diariamente, são diferentes eventos e práticas de letramento que se efetivam na profissão do engenheiro, letramentos que têm diversas intencionalidades e finalidades, se constituem de diferentes gêneros discursivos (Bakhtin, 2003) e se efetivam com variados interlocutores. Pesquisa recente (Franzen, 2012) discutiu e apresentou, a partir da voz de engenheiros, os gêneros mais recorrentes na esfera da engenharia. Dentre os gêneros discursivos citados, recebem destaque os projetos, relatórios e os artigos científicos.

Após essa breve seção de introdução, a partir da contextualização teórica, passamos à apresentação, discussão e análises dos dados no que concerne à oralidade, à leitura e à escrita no cotidiano de engenheiros na interface academia e mundo do trabalho. Por fim, apresentamos nossas considerações.

2 Linguagem em uso nas engenharias: entre academia e mundo profissional

O foco principal do presente artigo é relativo às práticas de leitura, escrita e oralidade de engenheiros na interface universidade e esfera profissional, conforme já exposto. Intentamos debater as implicações das práticas de letramento nessa interface academia e mundo do trabalho. Propomos, assim, uma construção acerca da nossa compreensão de letramento ou letramentos no plural. Segundo Terzi (2006, p. 03), os letramentos são "a relação que indivíduos e comunidades estabelecem com a escrita nas interações sociais", isto é, os letramentos estão ligados às situações e concepções de leitura e escrita que são desenvolvidas em determinados meios sociais.

Adotamos, neste trabalho, a concepção de letramento ideológico (Street, 2003), que compreende as atividades de leitura e escrita por meio da interação social nas práticas letradas. O sujeito pode, dessa forma, participar de diferentes meios sociais e ser membro efetivo de múltiplos letramentos. Nesta concepção de letramento, o desenvolvimento das capacidades de leitura e escrita colabora para que o sujeito se torne *insider* (Gee, 2005), isto é, membro efetivo de diferentes práticas de letramento.

As práticas de letramento estão essencialmente ligadas à esfera (Bakhtin, 2003) na qual acontecem, temos, por exemplo, o letramento familiar, religioso e acadêmico, que não se excluem, mas compõem novos panoramas de atuação social. Assim, o sujeito se constitui *insider* de múltiplos letramentos em diferentes esferas. Segundo Dionísio (2007, p. 210), os letramentos se apresentam "como um conjunto de práticas sociais, que envolvem o texto escrito, não do ponto restrito da linguagem, mas de qualquer texto", isto é, as capacidades de leitura e escrita vão além dos textos escritos, mas de todo e qualquer discurso (Bakhtin, 2003).

Compreendemos, assim, que, a partir da inserção nas diferentes esferas, o sujeito se torna membro efetivo em distintas práticas e eventos de letramento. Essas práticas de linguagem compreendem a interação com diferentes discursos e suas respectivas funções, pois cada situação discursiva exige do sujeito variadas capacidades e tomadas de decisão.

Na engenharia, há a interação com projetos, que envolvem números, textos e representações gráficas que impõem ao engenheiro a necessidade de interpretação, como afirma E01BR ao refletir sobre as atividades de leitura em sua atuação profissional:

> *A maioria dos textos que eu leio no meu trabalho, é a leitura de projetos que no caso não é bem uma leitura de textos que é mais uma interpretação e a parte de texto mais... é a parte de catálogo técnico e mais a parte burocrática do processo inteiro.*

A partir das palavras de E01BR, compreendemos que sua concepção de leitura engloba, além da decodificação, também a interpretação das informações que são expostas nos textos em questão. Sua atuação profissional, dessa forma, impõe que ele interaja e se aproprie das informações expressas nos documentos, de forma a agir sobre e com o material escrito. É a partir da relação do profissional com os gêneros em questão e sua tomada de decisão sobre esse material que vai se delinear e construir o fazer profissional, ou seja, o cotidiano profissional está ligado à interação com o documento escrito. A partir das colocações do sujeito, depreendemos que essa é uma prática de letramento habitual nesta área, visto que há a necessidade de executar comandos que são expostos nos projetos. A interpretação de projetos se caracteriza, assim, como uma prática de letramento inerente à esfera da engenharia (civil, nesta situação).

Ligada a esse saber de interpretação, está a capacidade de comunicação com diferentes interlocutores, pois os engenheiros participam de distintas comunidades discursivas em seu cotidiano, e se defrontam com a necessidade de passar informações a pessoas de diferentes papéis sociais, como salienta E01PT

> *Nós agora estamos a ter a experiência mais a nível de campo na empresa e... é preciso estabelecer comunicação seja com o nível mais baixo de operação, como...como o nível mais alto com o chefão, não é? E é preciso sempre saber comunicar e saber como apresentar as coisas, porque não adianta apresentar números, não adianta apresentar coisas técnicas... é preciso saber apresentar-se e saber expressar-se.*

A partir dos dizeres de E01PT, compreendemos que o sujeito, além de se comunicar com eficiência, se preocupa com a imagem de si mesmo em relação ao seu interlocutor, depreendemos também a necessidade de adequação da linguagem no campo da engenharia, há de se adaptar o discurso técnico a diferentes pessoas, distintas hierarquias e papéis sociais. O engenheiro precisa contar com um variado leque de possibilidades de comunicação, ele precisa se constituir *insider* em diferentes Discursos (Gee, 2005) a fim de poder participar de diversas práticas de comunicação.

Compreendemos que o profissional da engenharia, inserido em sua esfera profissional, lança mão de diferentes capacidades de leitura e escrita. E que toda e qualquer prática de letramento, introduzida em determinada esfera social, está inserida em um contexto de ideologias e atribuições axiológicas (Bakhtin, 2003), por isso, tem sempre sua finalidade. As práticas de leitura e escrita das quais os engenheiros fazem parte também estão inseridas nesses contextos e se dão sempre com uma intencionalidade.

Na atuação profissional, os engenheiros encontram diferentes motivações no que diz respeito à linguagem. E02PT explica que sua principal necessidade acerca das capacidades de leitura e escrita se encontra no âmbito profissional:

> *é a maneira de apresentar e convencer as outras pessoas a juntarem-se ao nosso lado, é mostrar aquilo que fizemos e a fazer com que elas valorizem aquilo que fizemos, ou seja, não basta só ser muito forte a nível teórico, a nível técnico e fazer um bom trabalho, é preciso saber vendê-lo, saber... saber, e principalmente na nossa área ainda por cima que envolve mexer com... mexer com pessoas, mexer com processos, é preciso saber como mexer, como fazer as pessoas estarem motivadas e compreenderem o sentido da mudança*.

Na fala de E02PT, compreendemos que o engenheiro precisa saber convencer as pessoas, o profissional deve se apropriar da comunicação de forma que consiga fazer com que seus interlocutores entendam e aceitem suas ideias. Não basta comunicar, é preciso fazer com que seu ouvinte compreenda e compartilhe das suas decisões. Mesmo porque nas esferas de atuação social, existem relações de poder que, inseridas nesse contexto mais amplo, acabam por refletir nas práticas de linguagem que nelas se efetivam. Dessa forma, o engenheiro lança mão de práticas discursivas que colaboram e representam sua atuação profissional, nessa interação entre locutor e interlocutor, a linguagem se apresenta como o meio pelo qual o profissional defende seus argumentos a fim de conseguir pôr suas ideias em prática. Outra função da leitura e escrita é a prestação de contas, como menciona E02BR:

> *Cada dia a gente tem que escrever o que foi feito na obra, e tem o orçamento que cada dia é escrito no diário o que está sendo executado, quantas pessoas trabalham, quantas horas por dia está sendo trabalhado, o material que está sendo usado e a gente pega na planilha o item do orçamento e coloca no diário o número da etapa que está sendo executada para ter um controle, né?*.

E02BR afirma que diariamente são feitos registros das atividades e recursos disponíveis a fim de que se tenha um balanceamento do progresso no trabalho. A intenção da escrita é prestar contas, mais uma vez a linguagem ganha um espaço de destaque nas práticas cotidianas, pois é o meio pelo qual são reportadas as situações diárias na esfera do trabalho. A articulação entre locutor e interlocutor, novamente marcada pelas relações de poder, enfatiza o papel social da linguagem no cotidiano profissional do engenheiro, que faz uso da comunicação para distintos objetivos e intenções. Segundo Guedes *et al* (2007, p. 10), "a intenção determina tanto a escolha do próprio objeto, seus limites e possibilidades de sentido, como a opção pelos recursos linguísticos, pelo gênero discursivo e pelo tipo de entonação, condicionadas a possibilidades historicamente situadas", ou seja, toda a estruturação do discurso passa pela intencionalidade da comunicação e pela situação historicamente situada, que considera também seu interlocutor e as relações de poder desempenhadas por locutor e ouvinte. Retomando o que disse E02BR, por exemplo, compreendemos que a forma como seu diário é escrito leva em consideração para quem e por que ele é escrito, ponderando-se as relações de poder que permeiam essa esfera, como o sujeito cita *pra ter um controle, né?*

Dessa forma, nos deparamos com as opções feitas pelos sujeitos na construção do discurso, escolhas que dizem respeito, também, aos gêneros discursivos (Bakhtin, 2003) selecionados para a comunicação. Os gêneros discursivos são os meios pelos quais a comunicação é efetivada, alguns deles são mais livres, outros mais fixos. Segundo Bakhtin (2006, p. 42), "cada época e cada grupo social têm seu repertório de formas de discurso na comunicação sócio-ideológica. A cada grupo de formas pertencentes ao mesmo gênero, isto é, a cada forma de discurso social, corresponde um grupo de temas". Quando tratamos dos gêneros, é importante enfatizar a diferença entre forma arquitetônica e forma composicional. O discurso é articulado levando-se em conta não apenas seu aspecto exterior, mas também as particularidades da situação da enunciação, condições de produção, e "suas relações dialógicas e valorativas" (Brait & Pistori, 2012, p. 378), esse plano mais amplo do gênero discursivo é chamado de forma arquitetônica. Já a forma composicional diz respeito à estruturação do discurso, às escolhas lexicais, semânticas e pragmáticas do falante (Bakhtin, 2003). Compreendemos, assim, que o sujeito organiza socialmente seu discurso articulando a forma composicional e a forma arquitetônica do gênero.

Na engenharia, os eventos de letramento estão ligados a alguns gêneros discursivos específicos, a pesquisa de Franzen (2012), já referenciada, apresentou alguns dos gêneros discursivos mais assinalados por engenheiros como os mais recorrentes em seu cotidiano profissional. Conforme já exposto, os gêneros estão relacionados à situação em que são utilizados, levando-se em consideração interlocutor, relações de poder e contexto mais amplo no qual são construídos, conforme destacam Brait & Pistori (2012, p. 375), "o conceito de gênero não se limita a estruturas ou textos, embora os considere como dimensões constituintes. Implica, essencialmente, dialogismo e maneira de entender e enfrentar a vida". Os gêneros discursivos estão ligados à situação de produção, à esfera na qual são construídos. Recorremos aos dizeres dos engenheiros para compreender como é a relação entre os eventos de letramento e os gêneros discursivos característicos na área da engenharia. E02BR esclarece sobre sua relação com o relatório:

> *O relatório é mais quando deu algum problema ou alguma solução que tem que dar ou alguma ideia. Daí, por exemplo, apareceu um problema lá na parede, daí eu escrevo pra eles que problema deu, que material eu vou usar, quanto que vai sair de armadura e de concreto e dou uma ideia pra eles aprovarem. Ou quando deu um problema e tem que explicar porque aquilo aconteceu.*

Depreendemos, pela fala e E02BR, que o relatório se torna um gênero fundamental em seu cotidiano profissional, pois apresenta uma função bastante específica. O engenheiro explica, ainda, qual a finalidade do relatório e como ele se apropria do gênero já no âmbito profissional, além de sinalizar novamente as relações de poder que se encontram em sua esfera profissional: *e dou uma ideia pra eles aprovarem*. O relatório, enquanto discurso produzido pelo engenheiro assume um papel de destaque em sua atuação profissional, pois é o meio pelo qual são (re)pensadas questões práticas do cotidiano profissional: sem o auxílio desse documento, a efetivação do trabalho de outros atuantes dessa esfera é prejudicada. A interação se apresenta, assim, como uma ponte não apenas entre interlocutores, mas também entre atuações sociais inseridas na esfera da engenharia. Ao comentar sobre a forma como teve o contato inicial com esses gêneros, ele afirma:

> *eu aprendi sozinho e um pouco na pós. Na graduação, quase nada porque não tem matéria pra isso, quase não tem matéria*.

E02BR problematiza a situação de não ter interagido com esses gêneros durante a graduação, apenas no curso de pós-graduação *lato sensu* que cursou e, então, entramos em uma discussão mais ampla: se as capacidades de leitura e escrita são características da atuação profissional do engenheiro, se há práticas e eventos de letramento nas engenharias, há a formação para essa atuação social durante a graduação?

Esse questionamento nos encaminha para reflexões acerca das formas de desenvolver as capacidades de leitura e escrita dentro dos cursos de engenharia. Não sob a ótica de que uma disciplina daria conta de desenvolver essas capacidades, mas no sentido de que os saberes em si precisam ser trabalhados nas disciplinas do currículo. O currículo, sob essa perspectiva, funciona como uma espiral na qual os conhecimentos vão sendo aprofundados e articulados de forma sistemática. Algumas metodologias trabalham nesse sentido em engenharia, são as denominadas teorias de aprendizagem ativa.

O trabalho com a aprendizagem ativa nas engenharias se efetiva por distintas metodologias, como o PBL *(Project-Based Learning)* e PLE *(Project Led Education)* que são ações que vêm dando resultados positivos no ensino superior em engenharia. Sob a ótica da aprendizagem ativa, o aluno é o sujeito que pesquisa e, aos poucos, constrói sua autonomia no processo de aprendizagem. Ao considerar o estudante o protagonista do processo de ensino e aprendizagem, a aprendizagem ativa possibilita que o futuro engenheiro (no caso ora abordado) entre em contato com as capacidades características de sua área de formação e, quando chega ao campo profissional, já tenha construído conhecimentos sobre as formas de interação verbal.

Para essa construção, traçamos paralelos entre os dizeres dos engenheiros em formação pelas metodologias de aprendizagem ativa e as falas dos profissionais formados pelo ensino tradicional. A fim de compreender melhor as distinções que são provocadas pelas diferentes abordagens teóricas no que concerne às práticas de linguagem em engenharia.

Como já exposto, durante as entrevistas, os engenheiros discorreram acerca das práticas e eventos de letramento de que participam em sua profissão. Todos afirmam que há uma ligação bastante próxima com a leitura, escrita e oralidade, mas os excertos assumem rumos diferentes quando se questiona se houve ou não preparação durante a formação acadêmica.

Concebemos as metodologias de aprendizagem ativa baseadas em projetos como fundamentais para a construção das atuações sociais, pois argumentam a favor da mudança, emancipação e autonomia, que são fundamentais para compor o perfil do profissional. Por estarem inseridos em sua esfera de trabalho, os engenheiros já participam dos eventos de letramento característicos do seu âmbito profissional, como enuncia E02PT:

> *A empresa inicialmente já tinha uma... uma... série de projetos, quatro, numa seleção e nós começamos a partir daí, entretanto na semana passada... há duas semanas... duas semanas, tivemos reunião com eles, reunião de andamento de projeto e aí percebemos de que, de que não iria dar para cumprir com os quatro dentro do tempo, que é muito curto.*

O estudante, inserido nas metodologias de aprendizagem ativa na engenharia, abre essa discussão sobre a inserção na empresa. Quando enuncia que *tivemos reunião com eles* e *percebemos de que não iria dar...*, depreendemos que E02PTe os demais acadêmicos desse curso estão inseridos dentro do planejamento, como já se fazem *insiders* das práticas e eventos de letramento da empresa e como participam ativamente das construções empresariais. Como o tempo dos futuros engenheiros é dividido entre a academia e a atuação profissional, os estudantes participam e integram as práticas discursivas de uma e outra esfera, de modo que as capacidades são desenvolvidas paralelamente.

Além de se apropriar das práticas de letramento da empresa, os futuros profissionais ainda têm a oportunidade de interagir com os interlocutores característicos de seu campo profissional, como explica E02PT:

> *mesmo o chefe da produção com quem tivemos reunião deu-nos, deu-nos hipóteses de melhoria e disse-nos onde é que deveríamos melhorar sem ser naquela... naquele espírito de repreender. Foi muito construtivo,*

Pinçamos da fala de E02PT a expressão *mesmo o chefe*, na qual o sujeito sinaliza que inclusive alguém que ocupa um cargo de chefia, de destaque dentro da companhia, abriu diálogo para os estudantes, dando a oportunidade de apresentarem e melhorarem suas ideias. Depreendemos o quão rica é a inserção nesse campo profissional, a interação com profissionais atuantes em sua área, diferentes papéis sociais e relações dialógicas. Ao falar sobre a forma como avalia a interação com as práticas de letramento na engenharia, E01BR argumenta:

> *hoje eu indicaria pra ter um número maior de cadeiras* [disciplinas] *pelo fato de como a nossa abordagem é muito superficial não dá tempo de aprofundar muito como se faz um relatório bem elaborado ou outro trabalho que você precise*.

Aqui, compreendemos a diferença entre a formação das capacidades de leitura e escrita nas metodologias de aprendizagem ativa e no ensino tradicional: o engenheiro, que chega ao mundo do trabalho sem a inserção prévia, sente-se despreparado para essas práticas, enquanto o que participa e vivencia o cotidiano da empresa já no curso de formação acadêmica se torna mais seguro em relação a essas capacidades.

Ainda acerca das formações na aprendizagem ativa e no ensino tradicional, a capacidade de falar em público é trazida ao centro das discussões. Ao refletir sobre a maior dificuldade para um engenheiro, E01BR diz que seria necessário

> *mais trabalho escrito e pra apresentar em público porque é uma coisa que a gente não faz. A gente não sabe falar em público.*

Em se tratando de um profissional que atua constantemente com pessoas, a comunicação é essencial, é importante que o engenheiro esteja confiante sobre essa capacidade para atuar de forma mais satisfatória na interação social com seus interlocutores, como salienta E02PT:

> *A oralidade, a parte de falar em si, eu acho que estamos bem. E depois existe a outra questão da leitura que é... que há um vocabulário e introduzir novas palavras e acho que não é tão bom assim.*

Diante disso, deparamo-nos com outra necessidade do engenheiro: a construção de metalinguagem da área, práticas de letramento que, segundo eles, não foram amplamente desenvolvidas. Compreendemos, assim, que a formação, embora caminhe no sentido de ampliar as capacidades relativas aos letramentos na engenharia, não dá conta da formação mais abrangente e instiga o aluno a pesquisar e ser o sujeito de sua própria autonomia.

Trazidas discussões acerca dos eventos e práticas de letramento, as concepções de gênero e as teorias de aprendizagem ativa, vislumbramos a relação entre o fazer profissional dos engenheiros e as atividades de leitura, escrita, oralidade e interpretação. São eixos que se integram para que as capacidades sejam fomentadas e desenvolvidas por parte dos sujeitos a fim de torná-los profissionais mais completos, críticos e desenvoltos nas suas esferas de trabalho.

3 Considerações Finais

Ao nos debruçarmos sobre as práticas de letramento que integram o cotidiano profissional de engenheiros e as implicações da leitura, escrita e oralidade nessa esfera de trabalho, depreendemos que o campo da engenharia é constituído por uma série de práticas específicas dessa esfera. As linguagens em uso na engenharia se apresentam como um frutífero campo de estudos no sentido de compreender a forma como são sistematizados esses conhecimentos em diferentes perspectivas metodológicas, podendo refletir em melhorias e mudanças nas atitudes responsivas de profissionais da área da educação em engenharia.

As práticas de linguagem não são um diferencial na identidade dos engenheiros, mas uma exigência imposta pela globalização e pelas inovações tecnológicas. Em sua atuação profissional, engenheiros se inserem em diferentes práticas de linguagem que são desencadeadas por variadas intenções e se constituem no diálogo com diversos interlocutores. Essas situações nas quais a linguagem desempenha um papel de destaque são efetivadas por gêneros distintos e, portanto, requerem que o profissional se aproprie desses gêneros. Mais do que saber o que dizer, é preciso saber como dizer, adequando seu discurso à situação enunciativa específica, de acordo com os pares com os quais interage.

Dentre os diversos gêneros que circulam na esfera profissional da engenharia, estão o relatório, o projeto e o diário, essas linguagens assumem diferentes funções no cotidiano: desde a prestação de contas até a persuasão dos pares no sentido de defender e apresentar ideias. Mais do que participar das práticas de letramento, os engenheiros encontram a necessidade de se apropriarem dessas linguagens a fim de se tornarem *insiders* na esfera profissional.

Quando refletimos sobre o trabalho com as múltiplas linguagens em engenharia, durante a formação acadêmica, compreendemos que ele é mais bem sistematizado quando empreendido de forma integrada, em espiral e contínua. Mais do que uma disciplina, é preciso que as linguagens sejam uma constante na formação do engenheiro. Nesse sentido, voltamo-nos para as teorias de aprendizagem ativa.

Ao participarem de cursos que tenham seu currículo pautado na aprendizagem ativa, os graduandos têm contato com seu campo profissional ainda durante a formação acadêmica. Inseridos em projetos, os estudantes participam das práticas de letramento características de sua atuação profissional, interagem com Discursos específicos de sua esfera e, pela inserção, se apropriam das linguagens em uso nas engenharias.

As teorias de aprendizagem ativa promovem uma maior articulação entre as disciplinas do currículo da engenharia e oportunizam, ainda, uma maior integração entre as esferas acadêmica e profissional. A leitura, a escrita e a oralidade se articulam e se constroem na medida em que o estudante participa dos projetos e das diferentes linguagens na interface academia e atuação profissional, o que oportuniza que a identidade de engenheiro seja construída também no que tange às linguagens, ainda durante o curso de formação acadêmica.

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The use of PBL in conducting an interdisciplinary project in public schools of Brazil

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Abstract

The Pró-futuro project aims at contributing to the education of public system´s high school students through workshops ministered by volunteer teachers using Project Based Learning (PBL). 6th semester Communications' students at the Catholic University of Brasilia (UCB) undertook the initiative in and allied communications and educational spheres. For this, we selected high school seniors (third year in Brazil) from Centro Educacional 3, located in Guara II (Brasilia, DF), to attend workshops geared to areas such as Writing, Languages and Codes in order to prepare them for the production and interpretation of texts . After the effective completion of the work, we could verify an analogy between educational practices focused on the field of communications and the teaching-learning relationship embraced in the whole integration process of professionals and students of Social Communications at a school environment, by using PBL. As a final product, the group recorded, through pictures and videos, all activities during classes for the posterior development of an audiovisual product, called Room 42.

Keywords: project based learning; education; interdisciplinary project; communication.

A utilização do PBL na realização de um projeto interdisciplinar na rede pública de ensino do Distrito Federal

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Keywords: Project Based Learning, Education, Interdisciplinary Project, Communication.

1 Introdução

Este trabalho apresenta a utilização do Project Based Learning (PBL) na produção de um projeto interdisciplinar, a partir de uma experiência realizada com alunos do 5º semestre do Curso de Comunicação Social da Universidade Católica de Brasília, na disciplina Jornalismo Especializado I. O projeto abrigou uma proposta que envolvia a aproximação com o mercado de trabalho a partir da elaboração de um pesquisa aplicada, com o desenvolvimento de produtos específicos para a área comunicacional, utilizando como base o PBL. O desenvolvimento da ideia proposta aos alunos consistia em uma iniciativa que gerasse frutos e resultados diretos para a comunidade que vivia próxima à Universidade. Somado a isso, o fato da matéria ser parte integrante do curso de Comunicação Social, habilitação em Jornalismo, fez com que os alunos optassem por iniciativas atreladas à área de formação. Os temas escolhidos recaíram prioritariamente em documentários, revistas eletrônicas, construção de sites e o desenvolvimento de um jornal impresso para a comunidade.

Para um grupo de alunos, composto por três integrantes, a ideia gerou resultados que romperam com os padrões de projetos apresentados e deu início a uma iniciativa inédita junto a alunos de uma escola pública do Distrito Federal, localizada próxima ao campus da Universidade Católica de Brasília, na cidade de Taguatinga.

Por meio da utilização e dos postulados do Project Based Learning, foi desenvolvido o Projeto Pró-Futuro, uma iniciativa que aliou o fortalecimento da relação de ensino-aprendizagem de alunos de uma escola da rede pública do Distrito Federal, o Centro Educacional 3, localizado no Guará II, na cidade de Brasília (DF), a partir de postulados da Educomunicação, propondo a inter-relação entre as duas áreas de estudo (Comunicação e Educação) em um viés interdisciplinar. A proposta envolveu professores voluntários com o público jovem a fim de prepará-lo para futuras oportunidades de estudo e trabalho. O projeto incentivou e atuou na intermediação da relação entre o corpo discente e docente no espaço escolar e aliou a esfera comunicacional à educativa.

Na experiência descrita, o PBL é estudado à luz da concepção de um projeto voltado para o ensino de alunos da rede pública do Distrito Federal. Criado com o objetivo de contribuir para a formação de jovens do ensino médio da rede pública do Distrito Federal, que estavam prestes a fazer vestibular, por meio de oficinas ministradas por professores voluntários, o projeto funcionou como uma preparação para o ingresso deles em uma universidade. Desta forma, visando a integração das técnicas de análise aos problemas reais, utilizou-se o PBL, a partir do princípio de que uma disciplina, voltada ao ensino do jornalismo especializado deve ensinar as inter-relações entre o mercado e a universidade.

1.1 O desenvolvimento do projeto

A Educação no Brasil ainda caminha a passos lentos e, apesar de algumas mudanças na estrutura educacional do país, jovens e crianças anseiam por iniciativas que os motivem a estudar e construir um futuro profissional. Diante disso, o Projeto Pró-Futuro surgiu com a intenção de transformar a realidade de um pequeno grupo de alunos de uma escola pública do Distrito Federal por meio do trabalho voluntário, em uma iniciativa que uniu a esfera acadêmica e escolar para o desenvolvimento de um projeto que fosse viável e acessível à comunidade envolvida. Partindo do princípio que o papel do estudante universitário é também, independente da área, contribuir para a sociedade como um todo, e sobretudo com a sua comunidade local, o grupo de universitários selecionou adolescentes que cursavam o terceiro ano do ensino médio do Centro Educacional 3, localizados no Guará II, em Brasília-DF, para assistirem oficinas voltadas às áreas de Redação, Linguagens e Códigos e prepará-los para a produção e interpretação de textos. A partir da conclusão efetiva do trabalho, verificou-se a analogia existente entre as práticas educacionais e a relação ensino-aprendizagem contida em todo o processo de inserção de profissionais e alunos de um curso de Comunicação Social no espaço escolar. Como produto final, foi elaborado um produto audiovisual, intitulado Sala 42.

Na prática, a experiência iniciou-se em sala de aula com um conteúdo teórico específico, voltado ao estudo do jornalismo especializado e seguiu para a realização dos projetos propostos, em torno de temas que pudessem gerar experiências aplicadas de produtos na área estudada ou que pudessem solucionar problemas identificados pelos próprios alunos. Nenhum grupo apresentou soluções para problemas específicos. Todos os 19 alunos que cursaram a disciplina optaram por trabalhar com projetos em temas como audiovisual, rádio, impresso e online.

Divididos em grupos de no máximo quatro alunos, cada conjunto desenvolveu ideias voltadas à divulgação de determinado assunto, a criação de veículos, como jornal e revista online e a produção de um documentário. O grupo em questão, atuou, por meio da utilização do PBL, em uma experiência que pode ser replicada em uma série de contextos, agregando diferentes atores e com a apresentação de resultados que podem beneficiar tanto o processo de ensino-aprendizagem dos alunos participantes, quanto da comunidade envolvida.

Tomando como público-alvo jovens alunos da rede pública de ensino do Distrito Federal, visando à formação de discentes que estavam prestes a fazer vestibular. Independente do perfil e das intenções dos alunos em relação ao futuro profissional, o projeto funcionou como uma preparação para o ingresso deles em uma universidade, bem como no mercado de trabalho.

O primeiro passo para a realização do projeto foi entrar em contato com a direção da instituição, que aceitou a proposta de imediato e disponibilizou o espaço para a realização das oficinas aos sábados. Seis professores voluntários com formação na área e atuação direta no mercado foram convidados e concordaram em dar aulas semanais de Redação e conteúdos relacionados à área de Linguagens e Códigos a partir de uma metodologia de aprendizagem ativa. Durante os meses de agosto a novembro de 2012, 25 estudantes da rede pública do Distrito Federal foram atendidos pelo projeto e aprenderam conhecimentos básicos da Língua Portuguesa e técnicas textuais para a produção e interpretação de textos. Hoje, uma das alunas que participaram das oficinas e assistiram ao conteúdo proposto pelo projeto, Rebeca Rocha, passou no vestibular para o curso de Relações Internacionais e iniciou os estudos na Universidade de Brasília (UnB), instituição que possui quatro campi, sendo estes nas regiões da Asa Norte (Campus Darcy Ribeiro), Planaltina (Faculdade UnB Planaltina), Gama (Faculdade UnB Gama) e Ceilândia (Faculdade UnB Ceilândia).

Atualmente, a Universidade de Brasília é a maior instituição de ensino superior do centro-oeste do Brasil e uma das mais importantes do país. Segundo a aluna ingressante no vestibular da UnB, as oficinas estimularam também os alunos a procurem alternativas além do ambiente proposto todos os sábados:

> Eu cheguei na sala, vi uma pessoa lendo um livro (de literatura) e falei: você está lendo esse livro? Ela respondeu que sim. Achei muito interessante esse estímulo, pois às vezes a pessoa não tem isso em casa ou na própria escola. O projeto ajudou bastante em relação a isso.

A intenção do projeto não era fazer com que o aluno simplesmente absorvesse conhecimento ou obtivesse um aprendizado total sobre os conceitos e técnicas, mas sim prepará-lo para qualquer oportunidade de estudo e trabalho. Mário Kaplún (1988) corrobora com a ideia de um espaço educativo gerador de ciência e informação, e ao mesmo participativo e fomentador do desenvolvimento. O processo educacional não deve ser individualizado e horizontalizado, mas sim dinâmico e baseado na participação ativa dos estudantes no ambiente escolar:

> Educar-se não é receber lições; é envolver-se num processo dialogal de múltiplas interações comunicativas. Por outro lado, se o autêntico desenvolvimento se fundamenta em formas de organização social baseadas na participação, uma comunicação que incentive a capacidade autogestionária das bases [da sociedade] se apresenta como uma dinâmica necessária para gerar o desenvolvimento (KAPLÚN, 1988, p.25).

Além disso, o projeto tinha como meta analisar a afinidade entre as duas áreas de estudo (comunicação e educação) e as possibilidades desse processo, por meio da aplicação do PBL. Por fim, incentivar e intermediar a relação entre o corpo discente e docente no espaço escolar. Durante o projeto, várias questões foram levantadas, inclusive sobre o papel dos comunicadores dentro do espaço escolar. Enquanto graduandos em Comunicação, seria possível intermediar processos educacionais dentro de uma escola? Algumas respostas foram obtidas com o estudo da Educomunicação , que propõe a aliança entre as duas áreas dentro de um novo modelo de educação. Para Soares (2004), o objetivo da Educomunicação é:

> [...] criar e fortalecer ecossistemas comunicativos em espaços educativos (o que significa criar e rever as relações de comunicação na escola, entre direção, professores e alunos, bem como da escola para com a comunidade, criando sempre ambientes abertos e democráticos. Muitas das dinâmicas adotadas no Educom apontam para as contradições das formas autoritárias de comunicação) (SOARES, 2004, p. 1).

A Educomunicação propõe estudos e iniciativas voltadas a alunos de diferentes períodos escolares, então, é relevante conhecer o perfil ideal do sujeito da educação para os meios. Segundo Toda e Terrero (1995, p. 67), os indivíduos têm características distintas, porém são pós-modernos, fragmentados, consumistas e pragmáticos. Logo, essas características devem ser estudadas com o objetivo de reconhecer inicialmente o público receptor das práticas educomunicacionais.Diante desse cenário, Barbero (2011), explica que o papel da escola na sociedade pós-moderna fora completamente transformado e esse ambiente tornou-se capaz de absorver novos métodos de aprendizagem:

> A escola deixou de ser o único lugar de legitimação do saber, pois existe uma multiplicidade de saberes que circulam por outros canais, difusos e descentralizados. Essa diversificação e difusão do saber, fora da escola, é um dos desafios mais fortes que o mundo da comunicação apresenta ao sistema educacional (MARTÍN-BARBEIRO, 2000, p. 55).

E foi justamente a partir desta difusão do saber a que Martin Barbeiro (2000) se refere que os alunos do Centro Educacional 3 aprenderam o valor da interdisciplinaridade e da colaboração em um ambiente criativo. Além disso, é possível afirmar que a língua portuguesa adquiriu um novo status e o aprender tornou-se parte do cotidiano dos alunos do Centro Educacional 3, a partir de uma experiência prática, que aproximou o mercado de trabalho com a realidade daqueles estudantes da rede pública de ensino do Distrito Federal.

2 Processo de aprendizagem e o Project Based Learning

No exercício profissional, tratar problemas reais envolve conhecimentos de diferentes domínios, suas inter-relações e implicações e a investigação de múltiplas "possíveis soluções". E o ensino de conteúdos específicos de disciplinas separadamente, utilizando uma abordagem expositiva "tradicional" muitas vezes não confere a contextualização necessária para a representação de situações dessa natureza (Savery, 2006).

O estudante pode ser levado a enfrentar situações similares às que enfrentaria no ambiente profissional por meio de um modelo de aprendizagem baseada em projetos (PBL), o qual envolve a identificação e solução de um número de questões ou problemas requerendo dos estudantes o planejamento para a resolução de problemas, tomada de decisão, pesquisa individual, e também o trabalho equipe, colaborativo, podendo resultar em produtos realistas.

A aprendizagem por projetos tem sua origem no método de projeto, inicialmente uma técnica introduzida para formação de arquitetos - por volta do século 17, Itália - e de engenheiros - no século 18, França - apoiada no treinamento de estudantes para o ofício, de forma prática, ao solucionarem problemas de concepção e construção e prepararem de forma autônoma planos e desenhos para obras e edificações. Estas tarefas já eram então denominadas "projetos" (Knoll, 1997).

O projeto como método de ensino foi introduzido nos Estados Unidos, em 1865, por William B. Rogers. No entanto, os proponentes do conceito de aprendizagem por meio de projetos foram Calvin M. Woodward (1887), que adaptou o conceito para o treinamento manual, Rufus W. Stimson (1912) em educação agrícola, e John F. Woodhull (1915) no ensino de ciências. Nesses casos, a instrução precedia a execução do projeto.

Em contraposição, Dewey, lidando com o ensino infantil, defendeu considerar os interesses e a experiência do aprendiz, colocando a criatividade no mesmo patamar de importância das habilidades técnicas. Nesse sentido, Richards alegou que o projeto não deve ser o objetivo final do processo educativo (Knoll, 1997).

Kilpatrick apresentou o método do projeto como a antinomia dos conceitos estabelecidos para o ensino levando-o a tema central dentro do movimento progressista educativo americano vigorante no início do século 20, a partir do seu trabalho "O Método do Projeto". O conceito do método requeria a motivação intrínseca do aluno e a noção tradicional de projeto foi expandida para qualquer tipo de atividade. Em seu conceito a aprendizagem por projeto era individual e situacional, assim diversas ações poderiam ser classificadas como projetos, desde que satisfizessem os critérios de autodeterminação e autossatisfação (Knoll, 1997).

Sendo assim, são dois modelos básicos do método de projeto: *i)* aquele no qual os estudantes aprendem, a *priori,* as habilidades e conhecimentos para depois aplicarem de forma independente e criativa no projeto prático, ou seja, o projeto é um fim no processo de ensino-aprendizagem; *ii)* O projeto passa para o centro do processo de ensino-aprendizagem, a instrução não precede o projeto mas é integrada e motivada por ele. Os aspectos relacionados ao todo passam a ser objetos de aprendizagem, desse modo, durante o processo as habilidades são desenvolvidas e a aprendizagem é propiciada.

Tendo como referência esses dois modelos as diversas abordagens baseadas em projeto mencionadas na literatura mantêm um conceito semelhante diferindo mais pela forma de aplicação, de acordo com a realidade associada à transmissão de conhecimentos e habilidades e da metodização do desenvolvimento do trabalho.

Mais recentemente, o termo Problem Based Learning (PBL) ficou conhecido a partir de experiências pioneiras na aplicação nas áreas médicas, fundamentadas na proposição de problemas reais e na formação de um ambiente de aprendizagem que motivou a participação ativa dos estudantes, garantindo oportunidades para o desenvolvimento de competências e a autonomia. A sua implantação curricular suscitou anos de questionamentos, críticas e de planejamento (BARROWS, 1994, 1996; HASLETT, 2001).

Campos (2009) indica que as diversas denominações que surgiram com o passar dos tempos modificaram apenas o foco de aplicação da aprendizagem, quando o projeto é o centro do processo de aprendizagem:

- PBL (Aprendizagem Baseada em Problemas) - aborda assuntos institucionais;

- PLE/PBLE (Project Led Education/Project Based Learning in Engineering, Aprendizagem Baseada em Projetos) - aborda assuntos ligados à comunidade;

- PPBL (Aprendizagem Baseada em Problemas e Projetos) - aborda assuntos relacionados à instituição e à comunidade;

- P3BL (Aprendizagem Baseada em Problemas, Projetos e Práticas) - aborda assuntos de interesse da instituição, da comunidade e da indústria.

A denominação PLE foi utilizada por Powell e Weenk (2003) para indicar a adoção de uma metodologia de ensino-aprendizagem ativa e colaborativa, baseada no aluno e no seu desempenho. Também se concentra no trabalho em equipe, no entanto desenvolve competências de ordem técnica e diferencia-se por criar simultaneamente, competências transversais como trabalho em equipe, disciplina, espírito crítico, iniciativa, entre outras, e relaciona conteúdos interdisciplinares de forma integrada.

Seguindo a observação de Hattum-Janssen (2007) "este método de ensino é superior as técnicas utilizadas em módulos ou sequências adotadas em sala de aula":

> In general, PLE can be regarded as a useful way to develop technical and non-technical competencies, as also stated by Drummond et al. (1998) who argue that developing competencies in a context that is similar to the context in which they will be used, is more beneficial than developing them in separate modules or in a traditional classroom setting (Hattum-Janssen, 2007).

A aprendizagem baseada em projetos, foco do presente trabalho, tem sido reportada na literatura também como Project Based Learning (PBL), metodologia em que são ampliadas as possibilidades de aplicação em diversas áreas de conhecimento, incluindo diferentes disciplinas, para diferentes níveis de idade e em diferentes domínios de conteúdo (Savery, 2006).

De particular interesse, é a fusão do PBL e da educação interdisciplinar, com ênfase nas Ciências Sociais. Uvinha e Pereira (2010) relatam ser um grande desafio a inserção do método na área de ciências humanas e sociais.

> Os olhares relacionados às ciências humanas e sociais buscam elucidar diferentes aspectos da realidade que, grande parte das vezes, não está ao alcance de procedimentos específicos [...]. O conhecimento desenvolvido nesses processos identifica os problemas e suas relações de determinação que são estabelecidas pelos próprios alunos na busca de entendimento do mesmo. Ao final, pode-se chegar a um determinado conhecimento específico que explicaria porque, no nosso exemplo, uma área específica é considerada de risco e porque uma comunidade ali se instalou. Mas saber isso não resolve o problema imediato, na medida em que tal fato não ocorre como exceção, mas permeia o tecido urbano. Somente a ação social pode encaminhar a resolução dos problemas (Uvinha e Pereira, 2010).

Nesse sentido, associar o PBL a um projeto de extensão universitária em parceria com a comunidade fornece o caso real a ser tratado e o apoio institucional necessário para a ação social promovida de modo a atender os diferentes aspectos levantados durante o desenvolvimento do projeto.

3 Análise e resultados obtidos

Para o desenvolvimento do projeto, buscou-se a realização de parcerias interdisciplinares, com o expertise de distintos profissionais, advindos de diferentes áreas, como publicidade e comércio. O grupo composto pelos três alunos da disciplina Jornalismo Especializado, responsáveis pelo projeto, buscaram junto a alunos do curso de Publicidade e Propaganda, a criação da identidade visual do Pró-Futuro. O material compreendia o desenvolvimento da identidade visual, de acordo com a Figura 1, que segue abaixo. Tal identidade foi utilizada para a confecção de camisetas, blocos de anotações, modelo para impressão de folhas e cores a serem utilizadas. A intenção era atrair os alunos para o projeto e personalizar o trabalho como um todo

Figura 1: Identidade visual do Pró-Futuro criada para o projeto.

Após a criação da identidade visual, a definição do público-alvo e obtidas as autorizações para realização do projeto na rede pública de ensino do Distrito Federal, a equipe determinou como seriam realizadas as oficinas junto aos alunos do Centro Educacional 3, do Guará II, em Brasília (DF). As oficinas tinham duração mínima de três horas e foram realizadas aos sábados. O assunto a ser abordado era escolhido pelos professores, que entravam em sala, de forma individual, durante o período de uma manhã, das 8hs às 11hs. Ao longo do projeto, seis professores ministraram aulas com conteúdos diferenciados.

Um segundo passo, foi a criação de uma conta em uma plataforma de comunicação entre a equipe organizadora, alunos, como forma de organizar e sistematizar a realização do trabalho entre professores e alunos e receber as demandas necessárias de forma mais ágil. O *Facebook* tornou-se um espaço de fala entre os envolvidos do projeto, em que, semanalmente, eram postadas fotografias tiradas nas oficinas, dicas, sugestões dadas pelos próprios professores, além de debates e discussões sobre os assuntos abordados em sala. Também serviu como meio de divulgação do trabalho ao público externo.

3.1 A produção de um documentário

O documentário foi um dos produtos desenvolvidos ao longo do projeto e teve suma importância para a sistematização das ações e a divulgação do mesmo. Primeiramente foi produzido um roteiro que serviu como base para a produção do documentário e foi escrito antes de iniciarem as oficinas. O texto apresentava as cenas a serem gravadas, os locais, datas.

Como produto final, o grupo optou pela elaboração de um documentário sobre o Pró-Futuro, pois essa seria uma forma interessante de devolver aos alunos, professores e demais envolvidos, o resultado da iniciativa. Além da gestão do projeto, os integrantes do grupo foram responsáveis pela elaboração do roteiro, captação de imagens, realização das entrevistas e, posteriormente, a edição do material. Além disso, foi produzida uma capa para DVD personalizada com fotografias tiradas ao longo do processo, apresentada abaixo.

As cenas ilustram o processo de ensino-aprendizagem, a relação entre o corpo docente e discente e as expectativas de todos os envolvidos durante a realização do projeto. Como forma de acompanhar esse processo, o grupo utilizou a técnica da entrevista sistemática com objetivo de comparar o início, o desenvolvimento e a conclusão do trabalho. Os alunos, professores e responsáveis pelo projeto foram entrevistados e filmados durante as oficinas. O produto audiovisual ganhou o nome de Sala 42 devido ao espaço que a escola ofereceu para a realização das aulas.

Figure 2: Sala 42, produto audiovisual desenvolvido como forma de sistematização do projeto realizado.

4 Considerações Finais

O Pró-Futuro ultrapassou as expectativas em relação aos objetivos do projeto. A simples intenção de realizar um trabalho, como forma de cumprir a exigência de uma disciplina foi superada. Após a conclusão do trabalho, a equipe continuou a realizar as oficinas na escola.

Primeiramente, a comunicação e a educação são áreas com grande possibilidade de diálogo. Comunicadores têm condições de desenvolverem trabalhos no espaço escolar voltados às questões educacionais e comunicacionais. No decorrer das aulas, a relação entre os alunos foi modificada. Não havia afinidade nem envolvimento entre as turmas e ao final da iniciativa todos os estudantes estenderam o contato para além da sala de aula.

Professores e membros da equipe diretiva perceberam uma melhora comportamental por parte dos alunos, e garantiram um aumento na motivação em relação ao estudo, além da preocupação com o futuro profissional. A aluna Rebeca, em uma das entrevistas, apontou a mudança observada pela professora: "A professora de português reparou a diferença nas redações. Ela passou a perceber que a gente está tendo uma postura diferente também na hora de escrever, na hora de falar, de se portar".

As filmagens e fotografias feitas durante as oficinas também revelaram um mudança no perfil dos alunos. No início, eles tinham dificuldade na elaboração e exposição de ideias frente às câmeras, mas no decorrer das atividades, eles passaram a dialogar com mais intensidade e criar respostas melhor fundamentadas. Os estudantes perceberam que o fato de serem alunos da rede pública, não os fazia ter menos condições que os demais em relação ao ingresso em uma universidade ou no mercado de trabalho.

As aulas ministradas pelos professores ofereceram um espaço de fala aos estudantes, que passaram a se expressar melhor diante dos assuntos globais. Já a equipe do Pró-Futuro desenvolveu competências comunicacionais, aprendizados em relação à gestão, além de técnicas da própria área de formação: produção, edição.

As contribuições do projeto descritas acima, somadas ao conceito de Educomunicação, são validadas a partir da abordagem trazida por Kaplún (1998), que confirma a potencialidade da comunicação, quando bem estruturada, no processo educacional. Ou seja, os métodos trazidos pela área de estudo têm o poder de modificar o perfil do emissor, no caso do aluno, tornando-o um "educando falante" ao invés de um "educando ouvinte". E é este educando que reflete a motivação e o objetivo fundamental do projeto, que incentiva a formação de um aluno por meio do suporte educacional aliado ao comunicacional.

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A successful experience combining PBL approach and sustainability in an engineering course

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Abstract

Students in the twenty-first century have yearned by new teaching methodologies to replace the traditional model in which the teacher has the knowledge that is transmitted in long speeches. PBL (Project Based Learning) appears to be a method that meets those demands for practices that lead to effective learning through experience. This paper aims to show how a PBL approach can lead to a successful experience, in which both the formal learning concepts as the acquisition of transversal skills can happen in a natural and enjoyable way for students. The project called "Campus Zero" is the result of the work of a group of freshmen in the Production Engineering course at the School of Engineering of Lorena of the University of São Paulo, which was challenged to produce a project with practical results to enhance the sustainability of the Campus of Lorena. The initial project had as objective the replacement of the conventional water distillers of the School undergraduation laboratory by the reverse osmosis equipment. During project development, the University released a public notice calling projects in the area of sustainability within the *campi*. The project was submitted and managed the financing of the equivalent to US$ 20,000. In order to measure and observe the progress of the project to promote environmental awareness of university students, a validated survey was used as a tool to assess progress in environmental awareness of students. Throughout the development of the project, the group acquired skills in several areas such as teamwork, time management to meet deadlines and goals, communication and expression, among others. Within USP Lorena, the project is taking such notoriety that the campus director has met with the group and showed his interest in continuing the project so that it becomes a permanent program of the School.

Keywords: Project Based Learning, engineering education, sustainability

Uma experiência de sucesso combinando a abordagem PBL e a sustentabilidade em um curso de engenharia

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Resumo

Os estudantes do século XXI têm almejado novas metodologias de ensino que substituem o modelo tradicional em que o professor detém o conhecimento, que é transmitido em longas palestras. A Aprendizagem Baseada em Projetos (ABPj ou PBL, das iniciais em inglês) aparece como um método capaz de suprir estas demandas por práticas que levem ao efetivo aprendizado através da experiência. Este trabalho tem como objetivo mostrar como a abordagem PBL pode levar a uma experiência de sucesso, na qual tanto o aprendizado de conceitos formais quanto a aquisição de habilidades transversais podem ocorrer de maneira natural e agradável para os estudantes. O projeto chamado Campus Zero é o resultado do trabalho de um grupo de calouros do curso de Engenharia de Produção da Escola de Engenharia de Lorena, da Universidade de São Paulo, que foi desafiado a produzir um projeto com resultados práticos para melhorar a sustentabilidade do campus de Lorena. O projeto inicial tinha como objetivo a substituição dos destiladores convencionais dos laboratórios químicos da graduação da Escola por equipamentos de osmose reversa. Durante o desenvolvimento do trabalho, a Universidade publicou um edital chamando por projetos que envolvessem a sustentabilidade nos campi, um projeto foi submetido e conseguiu-se a aprovação de o equivalente a vinte mil dólares. Com o objetivo de mensurar e observar o progresso do projeto em promover a conscientização dos alunos do campus, uma pesquisa foi aplicada como instrumento de medida da conscientização. Durante o desenvolvimento do projeto o grupo pode adquirir habilidades em muitas áreas, tais como trabalho em equipe, gerenciamento do tempo, comunicação e expressão, entre outras. Dentro do campus de Lorena, o projeto está se tornando tão notável que o diretor reuniu-se com o grupo a dar continuidade ao trabalho, de forma que o projeto se torne um programa permanente da Escola.

Palavras-chave: Aprendizagem Baseada em Projetos, educação em engenharia, sustentabilidade.

1 Introdução

O avanço do conhecimento tem ocorrido de forma cada vez mais acelerada, empresas exigem que os engenheiros possuam, de início, muitas habilidades além dos conhecimentos clássicos de sua área de atuação. A capacidade de se organizar em equipes; as habilidades de se expressar de forma objetiva e eficaz, de gerenciar o tempo adequadamente, de suportar o trabalho sob pressão e características como iniciativa, criatividade e resiliência têm feito parte do conjunto de características valorizadas pelos empregadores. Entretanto, se de um lado o empregador exige um profissional mais habilitado, do outro a universidade se depara com o desafio de capacitar esses futuros engenheiros com estas qualidades no mesmo tempo utilizado para o curso clássico de engenharia. Assim, a necessidade por métodos mais eficazes de ensino, em que o aluno possa ao mesmo tempo em que adquire o conhecimento clássico, desenvolver as tão desejadas habilidades transversais têm sido cada vez mais valorizadas.

Um duplo desafio se configura diante dos educadores do século XXI, pois além de lidarem com o avanço tecnológico rápido, há que se lidar paralelamente com a necessidade de prover os alunos de habilidades que antes só eram desenvolvidas com os anos de experiência no trabalho. (Casale, 2013)

Singhal, Bellamy e McNeill (1997) e Surgenor e Firth (2006) citam, em trabalhos que relacionam a taxa de retenção do conhecimento em função do método de ensino, que as aulas tradicionais apresentam taxas médias de retenção de apenas 5%, enquanto grupos de discussão, praticar fazendo e ensinar outros a fazer apresentam, respectivamente, taxas médias de 50%, 75% e 90%. Desta forma, fica evidente que as formas tradicionais de ensino, embora ainda largamente praticadas, estão longe de cumprir o papel que se espera da educação nos dias de hoje.

Nesse sentido, desde a década de sessenta, muitos estudos vêm sendo publicados a respeito de novas metodologias que são capazes de fazer com que os alunos tenham maior retenção dos conhecimentos (Rogers, 1961; Schmidt, 1983). Entre estes novos métodos de ensino, o que foi chamado de Aprendizagem Baseada em Projetos (PBL, das iniciais em inglês) tornou-se bastante conhecido e utilizado, o termo PBL foi originalmente utilizado por Don Woods, baseado no seu trabalho no curso de Química da Universidade McMaster's no Canadá, mas só tomou dimensão internacional depois que foi aplicado na Escola de Medicina da mesma Universidade. (Graaff and Kolmos, 2007). Entretanto, há autores que atribuem as origens do PBL aos anos 1900, quando o filósofo americano John Dewey comprovou o "aprender mediante o fazer" (Masson, 2012)

O método PBL se destaca por ter o aluno como figura central e principal no processo ensino aprendizagem e, segundo Lima (2005), por focar no aluno e em seu desempenho de modo a adquirir as competências definidas no planejamento do processo. Para Campos (2011), as principais características do método são: ter o aluno como o centro do processo; o desenvolvimento do projeto em grupos tutoriais e; ser um processo ativo, cooperativo e interdisciplinar. Acrescenta-se ainda que os temas a serem desenvolvidos pelos alunos precisam ter o apelo da atualidade, para que despertem o interesse por produzir resultados práticos.

Além destes aspectos, o ensino da engenharia também passou por uma transformação nos últimos anos, o que no passado era focado apenas no lucro e na produtividade, hoje deu lugar ao lucro e à produtividade sustentáveis, desta forma, vários congressos e publicações internacionais têm focado neste novo aspecto da formação do engenheiro, de forma a desenvolver competências que prezem pela ética e pela sustentabilidade para lidar com as mudanças de maneira sensata. (Valente, 2012).

Com objetivo de se integrar entre as escolas que formam profissionais de excelência com as habilidades exigidas pelo mercado de trabalho atual, o curso de Engenharia de Produção da Escola de Engenharia de Lorena (EEL) da Universidade de São Paulo (USP) vem, desde 2013, aplicando o método do PBL aos alunos ingressantes. O processo é conduzido através do professor da disciplina Introdução à Engenharia de Produção, que escolhe o tema a ser trabalha naquele ano juntamente com os demais professores envolvidos, coordena a formação de equipes, o esquema de tutorias e as apresentações e avaliações. No ano de 2013 o tema abordado foi *Um Campus Universitário Sustentável*, um tema que já vinha sendo muito discutido e trabalhado na mídia brasileira.

Este trabalho tem como objetivo relatar a experiência positiva vivida naquele ano por um grupo de alunos na condução do seu projeto, abordando aspectos que vão da aprendizagem das diferentes disciplinas envolvidas no esquema, passando pelas habilidades adquiridas pelos alunos e indo até às consequências positivas alcançadas pelo grupo na execução do projeto.

2 Aspectos Gerais do método aplicado

2.1 Guia do Projeto

Conforme relata Pereira (2013), todo o processo de aplicação do método PBL foi coordenado pelo professor da disciplina Introdução à Engenharia de Produção que, junto com os tutores, elaboraram um guia que foi entregue a todos os alunos matriculados na primeira aula do semestre. O guia teve como objetivo apresentar aos alunos o conceito de PBL e mostrar os principais objetivos a serem buscados ao longo do semestre. Além disso, o guia de projeto definiu as responsabilidades dos alunos e dos tutores. (GUIA DO PROJETO, 2013)

O Guia explica que as competências técnicas a serem adquiridas pelos alunos durante a realização do projeto interdisciplinar são as competências específicas pertinentes às disciplinas de apoio direto ao projeto (Figura 1), estas disciplinas são integrantes da grade curricular do curso no primeiro semestre e vêm fazendo parte do processo deste então. Os professores envolvidos no projeto foram contatados e todos, em 2013, faziam parte de uma equipe de suporte.

Cálculo I		Química Geral I
	Projeto Integrado	
Introdução à Engenharia de Produção		Leitura e Produção de Textos Acadêmicos

Figura 1: Disciplinas de apoio direto ao projeto (Pereira, 2013)

Além das competências técnicas, o Guia do Projeto esclareceu a expectativa de que os alunos desenvolvessem um conjunto de competências transversais (Tabela 1), que constituem o aspecto inovador na formação.

Tabela 1: Competências desejadas (Pereira, 2013)

Gestão de Projetos	**Trabalho em Equipe**	**Desenvolvimento Pessoal**	**Comunicação**
Capacidade de pesquisa	Autonomia	Criatividade / Originalidade	Comunicação escrita
Capacidade de decisão	Iniciativa	Espírito crítico	Comunicação oral
Capacidade de organização	Responsabilidade	Autoavaliação	
Gestão do tempo	Liderança	Autorregulação	
	Resolução de problemas		
	Relacionamento interpessoal		
	Gestão de conflitos		

2.2 As equipes do projeto e as suas ferramentas de apoio

As equipes foram organizadas pelo professor e eram formadas por seis ou sete alunos. Cada uma das seis equipes tinha, além dos ingressantes, um professor, no papel de tutor. O tutor, um professor da EEL, possuía certo conhecimento técnico sobre o problema e tinha a responsabilidade de orientar o grupo. O papel dos tutores se limitava a orientar o trabalho sem interferir nas decisões dos alunos.

O líder tinha a responsabilidade de convocar e conduzir as reuniões, distribuir tarefas e cobrar o seu cumprimento.

O secretário, escolhido entre os ingressantes, tinha a responsabilidade de registrar a evolução das discussões e da rotina de trabalho do grupo.

Três ferramentas de apoio ao projeto deveriam ser usadas pelos grupos: Blog, Diário de Bordo e um Protocolo de comunicação. O objetivo do blog era divulgar a evolução do trabalho do grupo de modo aberto, via web. O diário de bordo servia para ter um histórico detalhado do dia-a-dia do grupo. E o protocolo de comunicação era a ferramenta para comunicação interna, somente entre os membros do grupo e seu tutor.

2.3 O roteiro de aulas

Segundo o planejamento da disciplina, na primeira aula do curso, os alunos foram apresentados ao método de PBL e os grupos foram montados pelo professor, de forma aleatória. Nesta mesma aula, cada grupo recebeu a missão de se reunir e eleger o seu líder e secretário.

Nas semanas subsequentes os alunos foram submetidos às seguintes atividades: segunda aula, apresentação do blog; na terceira, os alunos assistiram a uma palestra com um diretor de RH de uma grande empresa sobre a importância do trabalho em equipe na vida profissional; na quarta os alunos foram submetidos a uma primeira avaliação do andamento da disciplina; na quinta semana apresentou-se a relevância da busca de artigos científicos; na sexta se sétima semanas os alunos tiveram atividades específicas sobre a Engenharia de Produção e entregaram um relatório preliminar sobre as atividades realizadas até então; na oitava aula, os alunos fizeram a apresentação do Projeto Preliminar e foram avaliados por uma comissão de tutores, que analisou suas propostas segundo a pertinência e a exequibilidade. As semanas seguintes foram dedicas a reuniões com os tutores e com o professor da disciplina, com objetivo de acompanharem o desenvolvimento do trabalho. A décima quinta e última semana do processo foi dedicada à apresentação final do projeto perante uma banca de seis professores, seguida da arguição por cada membro da banca. As equipes tinham além destas atividades, reuniões quinzenais com seus orientadores e a qualquer momento entre si.

2.4 O tema a ser desenvolvido

A proposta de PBL para o curso de Engenharia de Produção da EEL envolve motivar os alunos segundo temas que sejam pertinentes à formação dos alunos, bem como correspondam a assuntos da atualidade, de forma a serem por si só empolgantes e envolventes aos alunos. No ano de 2013, o tema escolhido foi *Um Campus Universitário Sustentável*.

2.5 A avaliação

A avaliação do projeto foi feita em duas etapas, a primeira na quarta semana de aula, quando os alunos fizeram uma apresentação para uma banca de professores sobre os projetos que pretendiam desenvolver, ali os grupos foram arguidos e tiveram a oportunidade de ouvirem as críticas dos professores da banca sobre suas pretensões. A segunda etapa constou da apresentação final para a mesma banca de professores, que atribuíram uma nota para cada grupo. Além disso, a nota final de cada grupo também foi composta da um componente de auto avaliação, correspondente a 20% da nota total, em que os alunos, em grupo, atribuíram notas a cada um dos componentes.

3 Desenvolvimento do projeto

3.1 O Projeto Campus Zero

Nas primeiras reuniões do grupo com objetivo de realizar uma prospecção de assuntos relevantes que pudessem atender aos objetivos traçados pelo tema escolhido, muitos assuntos e propostas foram discutidos pelos alunos. Assim, dentro de um esquema de *brainstorming* várias propostas foram levantadas, avaliadas e criticadas, dando ao grupo a oportunidade de exercitar sua criatividade e a capacidade crítica de avaliar o que era pertinente, exequível e com apelo suficiente para seguir adiante. Dentre as inúmeras propostas, a escolhida tratava de produzir um projeto para atender a um edital da Universidade de São Paulo, envolvendo todos os campi, cujo título era Desenvolvimento da Sustentabilidade na USP (Universidade de São Paulo, 2013).

Campus Zero foi o nome dado ao projeto cujos autores são os membros do grupo e coautores do presente trabalho. A utilização da água foi o foco escolhido para ser estudado mais profundamente e encontrar soluções mais sustentáveis. Além disso, outra preocupação foi a conscientização, sendo abordada por causa da sua importância no êxito de qualquer projeto que envolva sustentabilidade. Dentro desse contexto, o foco material do trabalho foi a economia de água e energia através da substituição dos destiladores tradicionais dos laboratórios de química da EEL pelos purificadores de osmose reversa, equipamentos de tecnologia mais moderna e econômica. Além disso, houve o foco de origem comportamental, dando ênfase a métodos eficientes sobre mudança de comportamento objetivando que as pessoas passassem a ter atitudes sustentáveis.

Para dar sustentação técnica ao projeto, os alunos realizaram um intenso trabalho para levantar o consumo de água e energia envolvidos no processo de produção de água destilada utilizada nos laboratórios de graduação da Escola. Assim, foi calculada a quantidade de água destilada utilizada em todas as aulas da graduação anualmente e a quantidade de água necessária para a sua produção, uma vez que os aparelhos utilizados eram destiladores convencionais, que utilizam uma grande quantidade de água tratada no resfriamento do sistema e cujo destino é o esgoto doméstico, configurando-se um grande desperdício de água potável. Além disto, contabilizou-se ainda a quantidade de energia elétrica gasta pelos destiladores. De posse destes dados, os alunos passaram a um trabalho de prospecção dos equipamentos de osmose reversa disponíveis no mercado, com suas capacidades e consumo de energia e insumos. Uma vez encontrado o equipamento adequado às necessidades dos laboratórios e, de posse de suas especificações técnicas, os alunos puderam montar um quadro comparativo mostrando que a economia de água seria da ordem de 3200 m^3 por ano. Uma vez contabilizados os custos de água e energia envolvidos nos processos e dos equipamentos de osmose, que deveriam ser adquiridos, os alunos mostraram que em 72 dias os custos com a aquisição dos aparelhos seriam cobertos pela economia gerada por eles.

Além disto, em todo projeto de sustentabilidade, apenas investimentos em soluções técnicas a fim de melhorar os índices de sustentabilidade ambiental não são suficientes, é preciso ir além da parte material do projeto. Para isso foi proposta a comunicação com as pessoas a fim de conscientizá-las. A princípio, conscientização remete à ideia já desgastada de apenas colar cartazes pelo campus com lembretes de "apague a luz", por exemplo. No entanto, somente isso não muda o comportamento das pessoas, não atingindo o objetivo do projeto. Sendo assim, métodos e ferramentas para mudança comportamental foram estudados, analisados e propostos, sempre por iniciativa dos próprios alunos.

Um dos métodos propostos pelos alunos para atingir a população da EEL foi o marketing social (KOTLER, 1992). Desse modo, o projeto visou também fazer o público refletir e entender os efeitos acerca de atitudes não sustentáveis, estimulando a mudar seu comportamento diante de situações que exijam isso. O plano fundamental era fazer com que o público comprasse a ideia e transformasse isso em hábitos, ações costumeiras. Finalmente, o projeto previa a concessão de bolsas-trabalho aos alunos do grupo para que pudessem desempenhar suas funções de "monitores" do projeto durante um período de um ano. Os próprios alunos se encarregaram de escrever o projeto dentro das normas propostas pelo Edital da Universidade. O trabalho foi revisado pelo tutor do grupo, que o submeteu à Reitoria. Após o período de análise, o projeto foi aprovado, com financiamento integral das atividades propostas, algo na ordem de vinte mil dólares americanos.

O cronograma seguido dentro da aplicação da disciplina estabelecia que a apresentação final, a ser realizada na última semana de aula, mostrasse qual seria a proposta dos alunos e quais resultados concretos poderiam ser alcançados com ela. Assim, a disciplina se encerrou com a apresentação do projeto final e o resultado concreto demonstrado foi a aprovação do projeto pela Reitoria e o financiamento.

3.2 Ações efetivas

Algumas campanhas específicas foram desenvolvidas pelo grupo na forma de organização de palestras para os alunos, colocação de cartazes nos banheiros e campanhas com propostas bastante específicas. Entre elas se destacou a campanha de conscientização dos alunos para a redução do uso de copos descartáveis no restaurante universitário da Escola. O trabalho baseou-se na coleta de todos os copos usados no restaurante durante três dias, depois disso, o grupo preparou cortinas com estes copos e as instalou em uma área de grande circulação do campus, com objetivo de despertar a curiosidade dos alunos. Alguns dias depois, o grupo passou de sala em sala apresentando uma pequena palestra sobre os benefícios para o meio ambiente com a substituição de copos descartáveis por canecas reutilizáveis. Como resultado, esta campanha possibilitou à Diretoria da Escola por em prática a restrição de fornecimento de copos no restaurante sem que houvesse reclamações por parte dos alunos, uma vez que já haviam passado por um processo de conscientização a respeito da necessidade de se ter um campus mais sustentável e cada um providenciado sua caneca. Outra ação concreta foi a troca dos equipamentos de destilação dos laboratórios pelos equipamentos de osmose reversa.

Além disto, como tinham como proposta ações que levassem a mudanças comportamentais, os alunos levantaram a necessidade do uso de um instrumento de medida que pudesse apontar objetivamente o quanto a conscientização sobre sustentabilidade seria alterada depois da execução do projeto. Assim, em uma intensa atividade de pesquisa e com o auxílio de um docente da área de estatística, procurado por iniciativa do próprio grupo, definiu-se que seria utilizado um questionário padronizado com o objetivo de medir o comportamento ecológico de forma adequada à realidade brasileira, que permitisse a compreensão desse fenômeno em nosso contexto sociocultural. O instrumento escolhido como confiável e adequado ao estudo dessa temática chama-se Escala de Comportamento Ecológico (ECE) (Pato e Tamayo, 2006).

Apesar de o compromisso com a disciplina ter sido encerrado em julho de 2013, o grupo continuou formado, dando sequência às ações propostas. O aprendizado não cessou, uma vez que durante a execução da fase posterior do projeto, novas oportunidades foram surgindo.

A partir do final formal da disciplina, grupo passou a se reunir com o tutor a cada trinta dias, quando mostravam o relato das ações desenvolvidas no período e suas perspectivas futuras. Durante todo o ano de 2014 a sistemática foi esta, e nesse período cada aluno recebeu uma bolsa de aproximadamente cento e cinquenta dólares pelo trabalho, o que fazia parte do projeto aprovado pela Universidade. Após quase dois anos, ou seja, em maio de 2015 ainda há ações planejadas, como a organização final dos dados levantados nos questionários e a publicação de artigos relatando a experiência global.

3.3 As competências adquiridas

A aplicação do PBL, dentro dos parâmetros já mencionados, possibilitou aos alunos o crescimento tanto dentro das disciplinas cursadas como dentro de aspectos interdisciplinares e transdisciplinares. Além, é claro, das competências transversais que sempre vêm com o processo.

No âmbito do crescimento dentro de cada disciplina, o aprendizado se deu principalmente devido à motivação que tiveram por estarem vivendo na prática a aplicação de determinados conhecimentos, como por exemplo, a necessidade de utilização de ferramentas do cálculo para a determinação do consumo de água e energia pelos sistemas de produção de água purificada; a aplicação de ferramentas da disciplina Leitura e Produção de Textos Acadêmicos perante a necessidade de busca e interpretação de textos técnicos para elaboração da revisão da bibliografia e da própria necessidade de produzir um texto completo, no caso o projeto a ser submetido à Reitoria; a utilização imediata de conceitos da Química Geral como destilação e osmose perante a necessidade de compreensão dos sistemas de produção de água existentes e propostos no projeto, além de aspectos ligados à qualidade da água, como condutividade, reações químicas, etc.

No aspecto interdisciplinar, as muitas sutis conexões entre as disciplinas acabaram por ser evidenciadas através das aplicações práticas que necessariamente fazem parte do método PBL; nesse aspecto pode-se citar como exemplos, a necessidade de ao mesmo tempo em que se interpretava um texto científico, compreender os conceitos ligados ao cálculo e à química neles contidos, ou a necessidade de se produzir um texto claro, conciso para o projeto, porém tecnicamente correto e dentro das normas de redação científica e, finalmente a percepção das conexões entre a Química e o Cálculo, em que conceitos como derivadas e integrais são utilizados nas deduções das equações que envolvem os conceitos de destilação e osmose.

Dentro de um conceito de transdiciplinaridade, definido como uma ação complementar da aproximação disciplinar, que faz emergir da confrontação das disciplinas novos dados que as articulam entre si e que dão uma nova visão da natureza e da realidade (dos Santos, 1995), pode-se afirmar que no decorrer da execução do projeto, vários conceitos não diretamente ligados aos conteúdos programáticos das disciplinas tiveram que ser estudados e aprofundados pelos alunos, de forma que a percepção que eles tinham dos assuntos estudados foi aprofundada e expandida. Como claro exemplo de transdiciplinaridade, no caso específico do projeto em questão, podem-se citar as comparações entre os dois métodos de produção de água purificada, que são estudados na disciplina Química Geral de forma estanque e isolada, mas que com a necessidade de aplicação prática no projeto tiveram de ser articulados de forma crítica, fazendo com que os alunos pudessem produzir comparações em aspectos qualitativos e quantitativos dos dois conceitos.

Finalmente, vale ressaltar as habilidades adquiridas pelos alunos no decorrer do processo, que são inerentes ao método do PBL e representam o seu diferencial. Através da estrutura de grupos, com lideres e secretários, os alunos têm a oportunidade de exercitar a liderança e a capacidade de comunicação, o senso de organização e de responsabilidade no cumprimento de cronogramas. A criatividade e pró-atividade são outras qualidades que advêm do PBL, já que o aprendizado está centrado no aluno, que passa a ser o principal ator no processo de aquisição e manipulação da informação. Com as apresentações para a turma, os alunos adquirem a capacidade de montar uma apresentação clara e sucinta, além do controle do tempo, importante limitante para quem ainda é inexperiente. Assim, pode-se afirmar que todas as habilidades mostradas no Quadro 1 foram criadas e ou exercitadas durante o processo de aplicação da disciplina e, no caso específico do caso em estudo neste trabalho, continuaram a ser desenvolvidas no decorrer da execução efetiva do projeto planejado pelos alunos.

O sentimento dos alunos quanto à experiência vivida é bastante positivo e pode ser resumida em uma frase, escrita por eles em um documento enviado recentemente ao tutor:

"No fim do semestre, os integrantes tinham o sentimento de muito conhecimento adquirido em pouco tempo e de realização por terem completado um projeto a partir de um método muito desafiador antes desconhecido a eles. Enfim, deu tão certo que o projeto existe até hoje, dois anos após seu início, e progredindo a cada dia, fruto dos benefícios que traz a metodologia PBL."

4 Conclusão

A aplicação do método da Aprendizagem Baseada em Projetos no Curso de Engenharia de Produção da EEL trouxe resultados muito positivos aos alunos. Em levantamentos realizados pelo coordenador da ação, pode-se verificar o alto grau de motivação atingido pelos alunos com o processo.

A articulação entre os professores das disciplinas envolvidas, no sentido de se discutirem as suas ementas para que as interconexões possam ser favorecidas é sempre desejável.

A escolha do tema de trabalho foi de grande importância para o sucesso da disciplina, tendo em vista que estava contextualizado dentro de uma realidade dentro da qual os alunos vivem e têm sido constantemente cobrados, tanto no âmbito social quando no profissional.

A possibilidade de realizar um projeto com resultados concretos deve sempre ser levada em consideração quando da preparação de um curso que utilize PBL, uma vez que esta é a motivação principal que leva os alunos ao desejo de aprender e empreender, sem o qual nenhum aprendizado é eficaz.

A continuidade da execução do projeto preparado durante a fase de aplicação da disciplina depois que esta termina é uma realidade a ser levada em consideração pelas escolas que aplicam o PBL, uma vez que quanto mais sérios e profundos forem os projetos executados pelos alunos, maiores são as chances destes se transformarem em ações reais e duradouras. Esta continuidade deve, na medida do possível, ser incentivada, pois se caracteriza como um importante motivador para as equipes participantes e serve de exemplo para as futuras equipes a serem formadas em anos subsequentes.

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The use of Problem-Based Learning for the Development of Management Competencies in Civil Engineering - Lessons Learned

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Abstract

This paper proposes to present the lessons learned from a qualification model of middle managers of construction companies based on learning problem-based approach - PBL (problem-based learning), for the development of managerial competencies and organizational learning. This approach enables the integration of theory and practice through a connection with real-life situations, encouraging managers to dwell on previous experience and knowledge. The key element in PBL is the problem as the focus of learning. The development of the model was based on an empirical study carried out in a construction company through various learning cycles involving a group of managers. Such cycles occurred through the process of individual, group and organizational learning interaction, since the development of organizational competencies depends on the combination of collective competencies (fuctional competencies) and individual competencies. As main conclusions, this study indicated that PBL may be adapted to an organization context, being effective in the qualification of managers: it triggers action over a real problem; it stimulates the understanding of the context; it helps understanding how and why managers find alternative solutions for the problem.

Keywords: competencies; organizational learning; problem-based learning.

O uso da Aprendizagem Baseada em Problemas para o Desenvolvimento de Competências Gerencias na Engenharia Civil - Lições Aprendidas

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Resumo

Este trabalho propõe apresentar as lições aprendidas de um modelo de capacitação de gerentes intermediários de empresas de construção, baseado na abordagem da aprendizagem baseada em problemas - ABP (problem-based learning), para o desenvolvimento de competências gerenciais e aprendizagem organizacional. Esta abordagem auxilia a integração da teoria e da prática através do relacionamento com situações da vida real, encorajando os gerentes a refletirem sobre a experiência prévia e o conhecimento. O elemento principal da ABP é o problema como foco da aprendizagem. O desenvolvimento do modelo foi baseado na realização de um estudo empírico em uma empresa de construção, no qual foram realizados vários ciclos de aprendizagem com um grupo de gerentes. Tais ciclos ocorreram através do processo de interação da aprendizagem individual, grupal e organizacional, uma vez que o desenvolvimento das competências organizacionais depende da combinação de competências coletivas (competências funcionais) e competências individuais. Como principais conclusões, este estudo indicou que a ABP pode ser adaptada ao contexto organizacional, sendo eficaz na capacitação dos gerentes: motiva a ação sobre um problema real; estimula a compreensão do contexto; impulsiona a busca da compreensão de como e por que os gerentes chegam a determinadas alternativas de soluções para o problema.

Palavras – chave: competências; aprendizagem organizacional; aprendizagem baseada em problemas.

1 Introdução

1.1 O Papel do Gerente no Contexto da Construção Civil

Bertelsen (2002) observa o processo de construção como um fenômeno complexo, que envolve um produto único e grandes investimentos de capital. Há múltiplos fatores controláveis e não-controláveis, ocasionando complexidade, variabilidade e incerteza, tanto no empreendimento quanto em cada atividade realizada (KOSKELA, 2000; BERTELSEN, 2002). O processo de produção é uma sucessão de etapas constituídas por atividades consideravelmente diversificadas, que envolvem a incorporação ao processo produtivo de uma grande variedade de materiais e componentes (FARAH, 1992).

Cabe ao engenheiro de obras o controle administrativo, o planejamento e controle técnico da obra, exercendo o papel de gerente de produção. Segundo Farah (1992), o controle técnico assume na prática uma posição secundária com relação às funções administrativas, que vão desde o controle financeiro do suprimento de materiais, pela mobilização e desmobilização da mão-de-obra e pelo acompanhamento da liberação de recursos com o agente financeiro. Como conseqüência, a função de controle técnico, muitas vezes, se restringe a um controle informal de resultados, com limitada interferência sobre o "como fazer" (FARAH, 1992).

O papel principal do engenheiro é resolver problemas, porém o erro mais comum é tentar fazê-lo sem conhecer a sua causa-raiz (BAZZO, PEREIRA, 1997). A definição clara do problema requer um estudo aprofundado da situação para determinar elementos essenciais para a sua solução. Dessa forma, o engenheiro assume muitas vezes o papel de "apagador de incêndios", centralizando o controle e a busca de resultados de curto prazo. Bohn (2000) caracteriza o "apagar incêndios" por sintomas, como falta de tempo suficiente para resolver todos os problemas; as soluções são incompletas; os problemas se repetem e se multiplicam; a urgência substitui a importância; muitos problemas se transformam em crises e o desempenho cai. Atualmente, esta postura do engenheiro de obras vem sendo bastante criticada por causa das mudanças que estão ocorrendo na construção civil, entre as quais, a necessidade de aumentar a produtividade, de diminuir desperdícios, de reduzir custos, de melhorar a qualidade dos projetos e de melhorar a qualidade dos serviços e do produto final.

O engenheiro deve ter uma visão mais ampla, não somente desenvolvendo soluções para problemas específicos, mas também pensando em soluções de forma sistêmica, procurando integrar todos os intervenientes envolvidos. Aliada à sua formação técnica específica deve possuir outros conhecimentos, como gestão de qualidade, segurança ambiental, custo e recursos humanos, o que melhora a sua qualificação profissional. Em virtude do que foi exposto, determinou-se como foco da presente pesquisa a necessidade de capacitação de gerentes de produção da construção em seu contexto organizacional.

1.2 Aprendizagem Baseada em Problemas

Segundo Frost (1996), esta abordagem auxilia a integração da teoria e da prática mediante o relacionamento com situações da vida real, encorajando os alunos a refletirem sobre a experiência prévia e o conhecimento. Esse mesmo autor afirma que a ABP é um método alternativo que surgiu para instruir profissionais, diminuindo a lacuna entre a teoria e a prática. Andrews e Jones (1996) declaram que, para desenvolver aspectos mais criativos e integrar a teoria com a prática, os professores têm empregado uma variedade de métodos, incluindo aqueles associados à resolução do problema, transferindo as mesmas estratégias da solução para a prática.

Albanese e Mitchell (1993) dizem que a essência da ABP é o problema como foco da aprendizagem. Esses mesmos autores indicam os requisitos para a aplicação da ABP:

a) apresentar um problema comum que o aluno espera poder resolver;

b) ser um assunto sério ou potencialmente sério, para ter um efeito no resultado;

c) ter implicações para prevenção;

d) fornecer input interdisciplinar e abranger uma ampla área de conteúdo;

e) apresentar tarefa real e concreta;

f) ter um nível de complexidade apropriado para ativar o conhecimento prévio do estudante.

Além disso, segundo Van Berkel et al. (1995), a ABP enfatiza a liberdade de aprendizagem como uma das características fundamentais para uma abordagem de aprendizagem baseada em problemas. Os alunos são estimulados a determinar, dentro de certo limite, o conteúdo do seu próprio estudo e selecionar tópicos que estimulam seus interesses. Merideth e Robbs (2003) apontam algumas vantagens da ABP, que são relacionadas a seguir:

a) desenvolvimento de um eficiente processo de raciocínio;

b) aumento na retenção de informações;

c) integração do conhecimento;

d) aprendizagem para toda a vida (life-long learning);

e) aumento da experiência;

f) melhor interação entre o aluno e o facilitador;

g) aumento na motivação.

Vale ressaltar que a ABP vem sendo utilizada nos cursos de graduação (BARROWS, 1986; MAMEDE; PENAFORTE, 2001; CARVALHO JR., 2002; RIBEIRO, 2005), necessitando ser adaptada ao contexto organizacional. Portanto, com as vantagens apontadas da ABP, verificou-se que essa abordagem poderia ser utilizada para a capacitação dos gerentes intermediários na construção civil dentro da empresa.

1.3 Objetivo

O objetivo deste trabalho consiste em apresentar as lições aprendidas de um modelo de aprendizagem baseada na ABP para o desenvolvimento de competências de gerentes de produção em empresas de construção civil dentro da organização.

2 Metodologia

2.1 Estratégia de Pesquisa

Neste trabalho, a estratégia de pesquisa adotada foi a pesquisa-ação. Conforme Thiollent (2000) é um tipo de pesquisa social com base empírica que é concebida e realizada em estreita associação com uma ação ou com a resolução de um problema coletivo e no qual os pesquisadores e os participantes representativos da situação, ou do problema, estão envolvidos de modo cooperativo ou participativo. A pesquisa-ação ocorre quando há interesse coletivo na resolução de um problema (SUSMAN; EVERED, 1978). A estratégia de pesquisa-ação foi adotada neste trabalho devido à necessidade de adaptação da ABP para o desenvolvimento de competências gerenciais na organização, pois essa abordagem é utilizada em cursos de graduação, geralmente nos cursos da área médica (MAMEDE; PENAFORTE, 2001). O processo da pesquisa foi concebido de modo participativo, envolvendo o pesquisador e os gerentes de produção. Diante de uma situação problemática, esses gerentes desenvolviam uma ação, que gerava uma reflexão e um planejamento de novas ações para o próximo ciclo pelo pesquisador.

2.2 Característica da Empresa

O estudo foi desenvolvido em uma empresa de construção de médio porte da Grande Porto Alegre, atuante nos segmentos de obras industriais, hospitalares e comerciais para clientes públicos e privados. Tem o corpo técnico de gerentes de produção constituído, em sua maioria, por engenheiros civis recém-formados, com pouca experiência. As obras que a empresa realiza caracterizam-se por serem rápidas, com elevado grau de incerteza, complexas e com uma duração relativamente curta, sendo o projeto em geral é desenvolvido simultaneamente à produção, havendo grande interferência do cliente.

Além disso, algumas obras são de reformas, realizadas sem a interrupção das atividades do cliente contratante, como obras em hospitais e em plantas industriais. Esta situação impõe restrições quanto à circulação de pessoas e materiais e horário de serviços, em função, principalmente, da segurança do trabalho e do ruído. A maior parte da mão-de-obra utilizada é subempreitada. A empresa possui um sistema de gestão da produção fortemente focado no sistema de planejamento e controle da produção (PCP), desenvolvido em parceria com o NORIE/UFRGS, ao longo de vários estudos. Este sistema integra ao PCP a gestão de segurança, desenvolvimento do produto e gestão de custos.

A empresa tem a certificação de sistema de gestão da qualidade com base na norma (ISO 9001:2000). Em 2003, a empresa programou, de forma sistemática, o processo de desenvolvimento de projetos, integrada à produção em dois empreendimentos do setor industrial. Nestes dois casos, houve a utilização de técnicas, planos e ferramentas específicos do processo de desenvolvimento do produto (PDP). Segundo os seus diretores, a empresa tinha necessidade de realizar um plano de desenvolvimento gerencial, por causa de inovações gerenciais que vinham sendo implantadas, havendo interesse em desenvolver novas competências.

2.3 Construção do Modelo de Capacitação

O modelo proposto foi fundamentado na revisão bibliográfica realizada, assim como nos resultados obtidos com a realização de dois estudos, com seis ciclos. A análise dos dados com o objetivo de estruturar a construção do modelo de aprendizagem baseado na ABP foi dividida em três perspectivas:

a) ABP: foram considerados o problema, o grupo tutorial (entende-se como o processo de interação grupal), o facilitador e o estudo individual;

b) aprendizagem individual;

c) aprendizagem organizacional

O processo de análise teve início com uma leitura exaustiva das transcrições das reuniões. Na análise, utilizou-se tanto a transcrição de trechos das reuniões como das entrevistas realizadas, de modo a cruzar as evidências existentes. Usaram-se também documentos da empresa (antes e depois das alterações): procedimentos, contratos, indicadores.

A história do grupo foi contada de forma seqüencial e cronológica, apresentando-se os fatos ocorridos julgados importantes para o pesquisador para o entendimento e a construção do processo de aprendizagem dos gerentes e da organização.

O processo de análise dava-se a cada ciclo da história do grupo de aprendizagem dos gerentes, com o objetivo de apresentar, de forma transparente, os fatos ocorridos e as suas interações no grupo. Para facilitar a análise e avaliação da abordagem foram definidos dois construtos principais: adequação da ABP ao contexto organizacional e a sua utilidade. Esses construtos foram desdobrados gradualmente ao longo do trabalho, de forma a agrupar as variáveis e fontes de evidências utilizadas.

3 Modelo de Capacitação de Gerentes Baseado na ABP

O modelo foi desenvolvido com base no ciclo de atividades da ABP, sendo adaptado, durante os dois estudos, pelo processo de interação do grupo e pelas avaliações no final de cada ciclo. Antes, porém, de descrever o modelo de capacitação, discute-se o ciclo do processo de aprendizagem individual, grupal e organizacional que permeia as etapas do modelo (ver figura 2). Esse ciclo foi desenvolvido durante o terceiro estudo com o objetivo de explicar como ocorria a aprendizagem organizacional. As fases do ciclo ocorrem simultaneamente com as etapas do modelo, correspondendo cada fase a uma das etapas.

O processo de aprendizagem inicia com o compartilhamento do conhecimento individual. Em seguida, a aprendizagem torna-se um processo social, partilhado pelas pessoas do grupo, gerando aprendizagem não só individual como também grupal. Depois da compreensão e da busca da solução para o problema compartilhada pelo grupo, discutem-se novamente os resultados com outros membros da empresa, motivando a proposição final para a solução do problema em forma de regras e procedimentos, o que cria condições favoráveis para a aprendizagem organizacional. A figura 1 mostra as quatro fases deste ciclo: compartilhamento do conhecimento, construção do conhecimento, difusão do conhecimento e armazenamento do conhecimento.

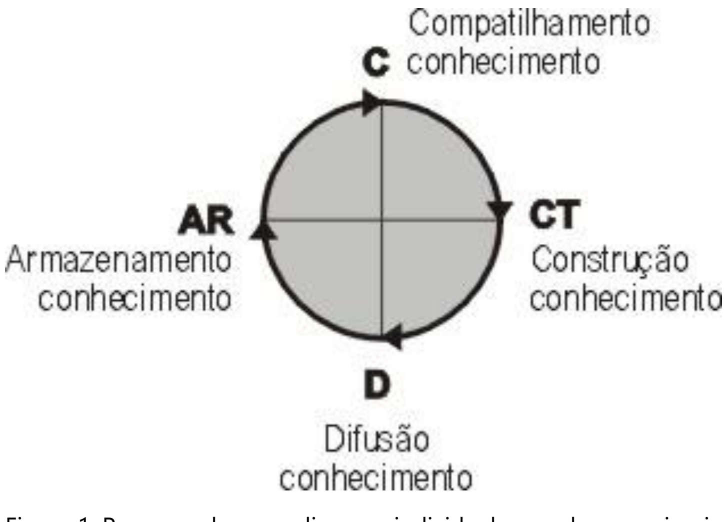

Figura 1: Processo de aprendizagem individual, grupal e organizacional no modelo de capacitação

O compartilhamento do conhecimento ocorre quando os gerentes de produção e os especialistas convidados relatam as suas experiências e trazem novas informações1. Segundo Huber (1991) e DiBella e Nevis (1999), pensando as organizações como sistemas sociais em que os funcionários estão continuamente gerando novas experiências, as empresas têm o potencial de estar aprendendo o tempo todo.

A construção do conhecimento ocorre quando os gerentes discutem as informações, atribuindo-lhes um significado. Isso aconteceu, por exemplo, na quarta reunião do primeiro ciclo, quando se debateu a elaboração

[1] Essas informações incluem fatos ocorridos, dados encontrados em documentos ou bibliografias, opiniões de especialistas e mensagens eletrônicas, que os gerentes trocavam entre si.

da matriz de responsabilidades da administração da obra, pois os gerentes entenderam que, com a matriz, diminuiria o treinamento da equipe administrativa no momento que houvesse rodízio dela entre as obras. Além disso, eles poderiam delegar mais as atividades. Conforme Huber (1991) e DiBella e Nevis (1999), é importante que o funcionário dê um significado à informação, de tal modo que o conhecimento gerado proporcione o ponto de partida para a ação.

A difusão do conhecimento refere-se à disseminação das idéias e soluções para os problemas organizacionais discutidas nas reuniões do grupo para a organização, que pode acontecer de maneira tanto formal (por exemplo, por meio de um seminário ou reunião) como informal (mediante o contato direto ou por e-mail). O armazenamento do conhecimento refere-se ao processo de acúmulo de informações por meio de documentos formais da empresa, tais como procedimentos, atas de reunião, contratos, que podem ser recuperados, constituindo a memória organizacional.

A figura 2 mostra o modelo, dividido em duas partes. Na primeira, denominada aprendizagem em grupo, o foco está na interação do grupo, ocorrendo o compartilhamento e a construção do conhecimento individual e grupal. Na segunda, a chamada aprendizagem organizacional, enfatiza-se a aprendizagem na organização, sendo caracterizada pela difusão e pelo armazenamento do conhecimento.

O modelo de capacitação é dividido em cinco etapas: problematização, ação, discussão de solução, planejamento da apresentação da solução e consolidação. O processo se inicia pela análise detalhada da situação, na qual se define o problema e se estabelecem as proposições iniciais para a sua solução. Na etapa seguinte, individualmente, aplica-se a solução na ação, acontecendo a reflexão sobre os resultados. Em seguida, na discussão de solução, apresentam-se os resultados para o grupo, havendo o questionamento. Caso se alcance o consenso na proposição final, o grupo gera um documento, procedimento ou uma nova prática e define a forma de apresentação da solução para a empresa. Em caso negativo, discutem-se novamente as proposições. Concluindo essa etapa, realiza-se uma avaliação do ciclo. Na fase de consolidação, apresenta-se o resultado e discute-se com a empresa a proposição final para a solução do problema. Em seguida, define-se uma nova situação problemática e, com isso, inicia-se um novo ciclo.

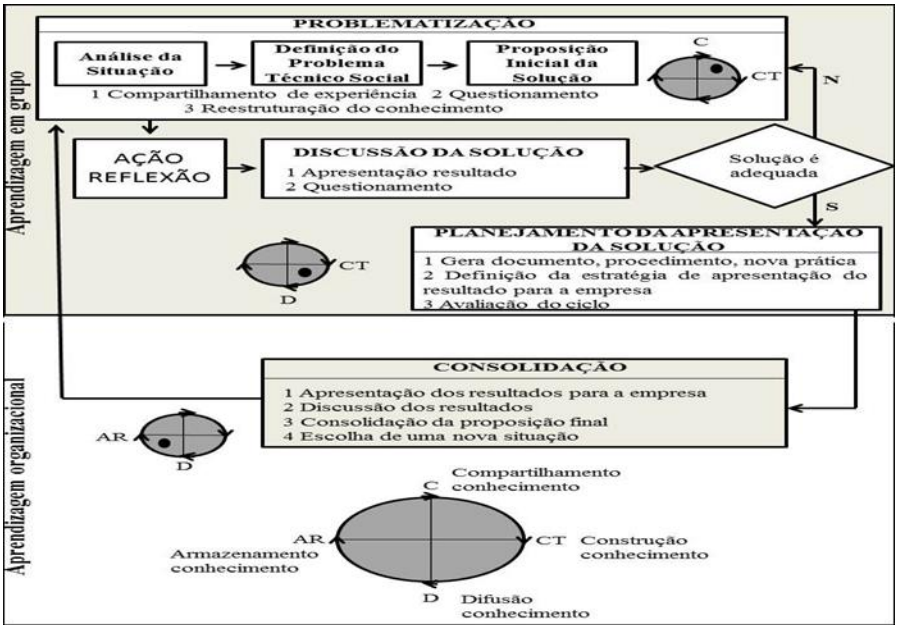

Figura 2: Modelo de capacitação

4 Lições aprendidas sobre a adaptação da ABP

Na realização do presente trabalho, foram aprendidas algumas lições em decorrência da adaptação da ABP ao contexto organizacional, que podem auxiliar e facilitar a realização de pesquisas similares:

a) O problema pode se apresentar inicialmente como uma situação problemática, devendo ter as seguintes características: alinhado aos objetivos da organização e aos interesses do grupo (coletivo); de preferência real e que esteja ocorrendo no momento (vinculado ao dia-a-dia); relacionado com os processos gerenciais; relevante para a prática profissional; a decisão do curso de ações a serem tomadas para sua resolução e implementação deve ser de responsabilidade do gerente de produção; levar em consideração os aspectos humanos, sociais e técnicos Isso faz com que o problema estimule a aprendizagem tanto individual, quanto grupal e organizacional. É preciso que os membros do grupo entendam a necessidade das mudanças e das melhorias.

b) Deve-se apresentar um resumo dos princípios da abordagem de aprendizagem proposta aos membros do grupo, de modo que os participantes entendam-nos e tomem consciência da sua responsabilidade no processo de aprendizagem.

c) Deve-se estabelecer um contrato de grupo entre os membros participantes no qual constem informações, como horário da reunião, tolerância de atraso e número de faltas. Dessa maneira, ficam claros os objetivos do grupo, direitos e deveres, estimulando a participação ativa dos envolvidos e a busca de meios de reforçar o trabalho de grupo para superar as expectativas.

d) Alguns envolvidos com o problema que não pertencem ao grupo podem ser convidados a participar de reuniões. O número máximo de participantes não deve exceder a dez, de modo a facilitar uma maior interação e participação de todos os membros na reunião.

e) Recomenda-se no máximo cinco reuniões para o fechamento de um ciclo de resolução do problema, com a duração de duas horas. Assim a reunião torna-se mais eficaz, facilitando o processo de aprendizagem para os membros do grupo. Deve ser escolhido entre os membros do grupo um coordenador que estimule os membros da equipe a compartilhar ideias sobre as questões, e um redator para cada reunião, encarregado de registrar as proposições, decisões e as ações do grupo.

Ressaltando que essas lições foram evidenciadas através do processo de análise que teve início com uma leitura exaustiva das transcrições das reuniões. Na análise, utilizou-se tanto a transcrição de trechos das reuniões como das entrevistas realizadas, de modo a cruzar as evidências existentes. O processo de análise dava-se a cada ciclo da história do grupo de aprendizagem dos gerentes, com o objetivo de apresentar, de forma transparente, os fatos ocorridos e as suas interações no grupo.

5 Conclusão

A adaptação da ABP ao contexto organizacional é viável, pois possibilita a capacitação dos gerentes, motivando-lhes ação sobre um problema real; estimula a compreensão do contexto; impulsiona a busca da compreensão de como e por que os gerentes chegam a determinadas alternativas de soluções para o problema e desenvolvem seus objetivos em relação às alternativas para o problema. Entretanto, como os gerentes não desenvolveram a aprendizagem autodirigida, essa abordagem tornou-se limitada, sendo necessário o emprego de recursos externos para a aquisição de novos conhecimentos a fim de possibilitar que a organização desenvolva maior capacidade de inovação. Apesar de a literatura apresentada sobre aprendizagem de adultos indicar que os indivíduos se sentem mais motivados quando são responsáveis pela sua própria aprendizagem, percebeu-se que os gerentes de produção ainda não estavam preparados para assumir o seu próprio desenvolvimento e gerenciar a sua própria carreira, adequando-se ao perfil exigido da empresa.

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Use of Active Strategies in Engineering Education in Brazil: a systematic mapping experiments from the publications produced in COBENGE

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Abstract

There is yet in engineering education in Brazil a predominance of realization the educational process from the use of traditional learning strategies that prioritize the knowledge learned by the teacher, which compromises the training requirements demanded by today's society. The Active Learning Strategies focus on the knowledge in the student, not the teacher, seeking a more integrative and interdisciplinary knowledge. It is observed that the Active Learning Strategies possible to develop skills that the current social dynamics demand of new engineers, such as pro-activity, leadership, teamwork, and enable the student to learn to learn. It is intended this work to quantify, from a systematic mapping, the articles published in the Brazilian Engineering Education Congress (COBENGE), the main forum for engineering education studies in Brazil on Active Learning Strategies for the period 2007 to 2014.

Keywords: Active Learning Strategies; systematic mapping; COBENGE.

Uso de Estratégias Ativas na Educação em Engenharia no Brasil: um mapeamento sistemático de experiências a partir das publicações realizadas no COBENGE

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Resumo

Há ainda na educação em engenharia no Brasil uma predominância da realização do processo educacional a partir do uso de estratégias de aprendizagem tradicionais, que priorizam o conhecimento aprendido pelo professor, o que compromete os requisitos de formação exigidos pela sociedade atual. As Estratégias Ativas de Aprendizagem (EAA's) focam o conhecimento no aluno e não no professor, visando um conhecimento mais integrador e interdisciplinar. Observa-se que as EAA's possibilitam o desenvolvimento de competências que a atual dinâmica social demanda dos novos engenheiros, como a pró-atividade, liderança, trabalho em equipe, além de possibilitar ao aluno aprender a aprender. Pretende-se nesse trabalho quantificar, a partir de um mapeamento sistemático, os artigos publicados no Congresso Brasileiro de Educação em Engenharia (COBENGE), principal fórum de estudos da educação em engenharia no Brasil, sobre Estratégias Ativas de Aprendizagem durante o período de 2007 a 2014.

Palavras-chave: Estratégia Ativa de Aprendizagem; mapeamento sistemático; COBENGE.

1 Introdução

Uma série de transformações ocorridas no cenário social, motivada, especialmente, pela evolução científica e tecnológica, e pelo processo de globalização, vem repercutindo no âmbito educacional. Mudanças na estrutura física dos ambientes escolares e universitários, com a presença das Tecnologias de Informação e Comunicação (TICs); e o fortalecimento de modalidades educacionais, como a Educação a Distância; vêm sendo observadas. Outro destaque pode ser dado às alterações ocorridas no processo de ensino-aprendizagem.

Tradicionalmente, a forma de ensino-aprendizagem é marcada pela posição central do professor no processo, considerado como o detentor do saber. Os estudantes aparecem neste cenário como seres passivos, conforme afirmava o educador brasileiro Paulo Freire, em sua teoria da educação bancária, como repositórios de conhecimentos. Com as alterações no cenário global e o avanço das TICs, pôde-se observar o fortalecimento de estratégias ativas de aprendizagem, cujo objetivo primordial é envolver o estudante no processo educacional, responsabilizando-o também pela sua aprendizagem. Problemas, projetos, jogos etc. são recursos que contribuem para desencadear o processo de aprendizagem em que os estudantes participam como elemento central, ativamente, em busca de soluções para situações que envolvem desafios, disponibilizadas pelos professores, a fim de promover o desenvolvimento de competências, habilidades e atitudes.

No Brasil, no âmbito da Educação em Engenharia, percebe-se a preocupação em formar engenheiros qualificados para atuarem na sociedade contemporânea. Um exemplo disto, encontra-se na elaboração da Resolução 11/2002, pelo Conselho Nacional de Educação (CNE), em debates realizados com instituições como a Associação Brasileira de Educação em Engenharia (ABENGE). Tal resolução institui diretrizes curriculares nacionais para os cursos de graduação em Engenharia e aponta a necessidade do desenvolvimento de algumas competências fundamentais na formação em engenharia (e.g. identificar, formular e resolver problemas de engenharia; e assumir a postura de permanente busca de atualização profissional). Acredita-se que uma das formas de conquista dessas competências é por meio do uso de estratégias ativas de aprendizagem, tais como o *Poblem Based Learning* (PBL) e o *Project Based Learning* (PjBL).

Neste sentido, este trabalho busca contribuir para a compreensão de como se encontra a situação das estratégias ativas na educação em Engenharia no Brasil. Para tanto, apresenta um mapeamento sistemático realizado nos Anais do Congresso Brasileiro de Educação em Engenharia (COBENGE), apontado como principal fórum de educação em Engenharia no país. O objetivo é mostrar como vem ocorrendo a implantação das estratégias ativas de aprendizagem na educação em cursos de engenharia, tomando-se como referência o período que compreende os anos de 2007 a 2014.

2 Congresso Brasileiro de Educação em Engenharia

O Congresso Brasileiro de Educação em Engenharia é considerado o mais importante fórum de reflexão sobre educação em Engenharia no Brasil. O evento é idealizado e promovido pela Associação Brasileira de Educação em Engenharia de reunir escolas e professores para, junto com órgãos governamentais e outras entidades interessadas no ensino de engenharia, compartilhar experiências, promover debates e propor estratégias para formar profissionais cada vez mais qualificados e capacitados para o atendimento das necessidades do País.

Segundo Tozzi, em 2013 o COBENGE em sua 41ª edição congregava mais de 150 instituições de ensino em todo o Brasil, além de órgãos oficiais e um grande número de professores associados. O COBENGE reúne, praticamente, representantes de todos os órgãos oficiais e instituições de ensino, além de empresas e profissionais interessados na melhoria e no desenvolvimento da engenharia nacional. O reconhecimento da importância desse evento pode ser evidenciado pelo número de participantes e pelo contínuo incremento no número de trabalhos apresentados em cada nova edição (TOZZI, 2013).

A cada ano o COBENGE é organizado por uma Instituição de Ensino Superior- IES em uma região diferente do país, tendo um coordenador responsável pelo desenvolvimento das atividades do evento. Nas últimas edições sua programação contempla as seguintes atividades:

- Sessão solene de abertura;
- Mesas redondas com apresentações de palestrantes convidados, seguidas de debates com a plenária;
- Sessões Técnicas de apresentações de artigos aprovados pela Comissão Técnico-Científica do evento;
- Sessões Dirigidas (SD) com apresentações de artigos selecionados pela respectiva Comissão Organizadora, seguida de debate com os participantes da SD;
- Sessões com apresentação de artigos no formato de pôster;
- Fórum Nacional de Gestores de Instituições de Educação de Engenharia;
- Minicursos oferecidos a professores e alunos;
- Atividades sociais e culturais;
- Exposição de instituições, entidades, equipamentos e livros, relacionados à educação em engenharia, bem como à divulgação da cultura da cidade/região;
- Assembleia da ABENGE, com a participação dos associados, onde são tratados os assuntos da pauta estabelecida pela Diretoria, que inclui prestação anual de contas, escolha do local do COBENGE e assuntos gerais.

3 Metodologia

O presente artigo realizou o Mapeamento Sistemático identificando as publicações acerca de EAA no Congresso Brasileiro de Educação em Engenharia- COBENGE. Inicialmente foram avaliados artigos referentes aos anos de 2007 a 2014, desses artigos foram selecionados 98 pertinentes para a pesquisa. A coleta dos artigos foi realizada no site oficial do COBENGE através dos Anais disponibilizados, a seleção foi do artigo se deu por meio de palavras chaves e critérios de inclusão e exclusão que serão apresentados posteriormente.

Segundo Kitchenham, o Mapeamento Sistemático(MS) é projetado para fornecer uma ampla visão de uma área de investigação, determinando se existe evidência de pesquisa sobre um tema e fornecendo uma indicação da quantidade da evidência. Os resultados de um MS podem identificar áreas adequadas para a realização de Revisões Sistemáticas da Literatura e também áreas onde um estudo preliminar é mais adequado (Kitchenham et al., 2007).

O objetivo da seleção dos artigos foi identificar publicações que respondessem as Questões de pesquisa presente na seção 3.1, reunindo informações acerca da aplicação de Estratégias Ativas de Aprendizagem aplicadas nos cursos Engenharia do Brasil com relatos de experiência no COBENGE.

3.1 Questões de Pesquisa

Um dos passos fundamentais do Mapeamento Sistemático é a definição de questões de pesquisa, Segundo Petersen, o principal objetivo do mapeamento sistemático é fornecer uma visão geral de uma área de pesquisa, e identificar a quantidade e tipo de pesquisa e os resultados disponíveis dentro dela. Muitas vezes as pessoas querem mapear as frequências de publicação ao longo do tempo para ver as tendências. Um objetivo secundário pode ser a identificação dos fóruns em que a pesquisa na área foi publicada. Essas metas são refletidas em questões de pesquisa de ambos os artigos (PETERSEN, et al., 2007).

Para desenvolver a presente pesquisa foram definidas as seguintes questões:

Q1- Quais são as estratégias ativas de aprendizagem (EAA)?

Q2- Quais são as estratégias ativas de aprendizagem (EAA) mais utilizadas?

Q3- Em quais instituições são utilizadas as EAA?

Q4- Quais instituições mais relatam experiência as EAA?

Q5- Quais os cursos que usam a EAA?

Q6- Qual o crescimento de artigos publicados ao longo dos anos sobre EAA?

Q7-Quantos artigos foram analisados?

Q8- Quantos artigos foram selecionados por ano? E no total?

Q9- Quais categorias?

3.2 Estratégias de Busca

3.2.1 Palavras Chaves

Para o levantamento dos artigos foram considerados os que em seu título fazem referência a alguma destas expressões: "PBL", "Problem Based Learning", "estratégias ativas de aprendizagem", "aprendizagem baseada em problemas", "ABP", "aprendizagem baseada em projetos"; "active learning"; "PjBL"; "Project Based Learning". Os resultados adquiridos serão direcionados pelas publicações sobre o Problem Based Learning (PBL) e o Project Based Learning (PjBL), pois, verifica-se com os trabalhos já desenvolvidos, que são as principais EAA'S utilizadas pelos cursos de Engenharia no Brasil.

3.2.2 Critérios de Inclusão e Exclusão

Para Petersen, os critérios de inclusão e exclusão são usados para excluir os estudos que não são relevantes para responder às questões de pesquisa. A partir de tais critérios descobrimos o que é útil para excluir documentos que só mencionaram o nosso foco principal (PETERSEN, et al., 2007). Após selecionar os artigos identificando as palavras chaves no título, foi realizada a leitura dos resumos e introdução dos mesmos para verificar se o conceito central na área era realmente tratado no artigo ou apenas citado no resumo sem abordá-lo mais amplamente. Esse critério foi utilizado para excluir artigos que não se mostraram relevantes para a pesquisa.

Dos artigos selecionados foram extraídos dados que serão apresentados e discutidos na seção de Resultados e Discussões do presente artigo. Foi desenvolvida também uma tabela de categorias para analisar qual o foco dos artigos selecionados quantos a aplicação das EAA'S, tal tabela também é apresentada na seção supracitada.

4 Resultados e Discussões

A partir do levantamento feito dos artigos publicados entre os anos de 2007 e 2014 é possível perceber um aumento de publicações sobre Estratégias Ativas de Aprendizagem ao longo dos anos pesquisados. Tendo também em consideração que o COBENGE vem estimulando a discussão sobre o assunto como palestras, sessões dirigidas, grupos de discussão etc. Percebe-se que em 2007 foram 6 artigos publicados; em 2008 foram 11; em 2009 foram 5; em 2010 foram 5; em 2011 foram 12; em 2012 foram 15; em 2013 foram 15 e em 2014 foram 29 artigos publicados. Tal crescimento pode ser observado na Figura 1.

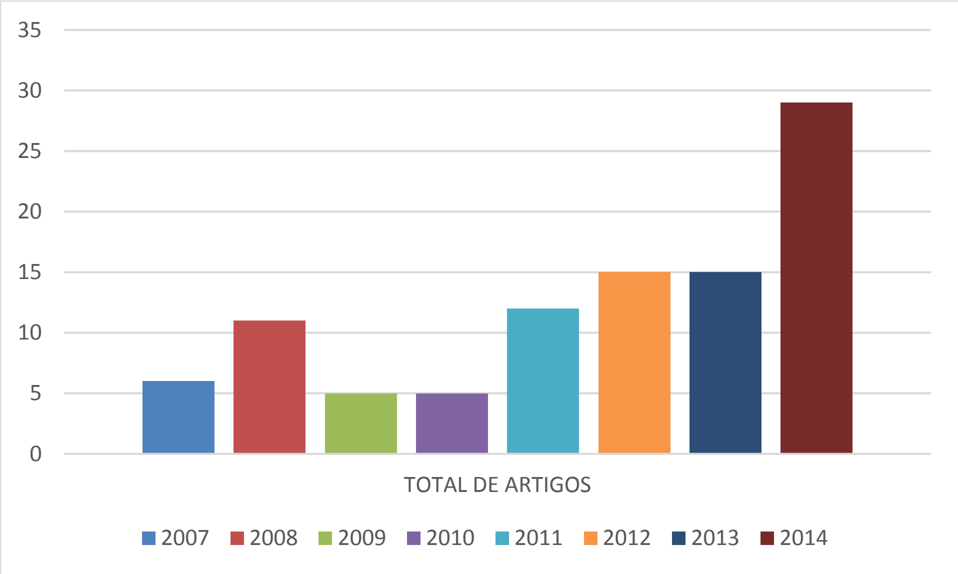

Figura 1: Gráfico de total de artigos por ano

Observou-se com os resultados da pesquisa que as estratégias que são mais relatadas nos artigos do COBENGE são o Aprendizado baseado em problemas (Problem Based Learning - PBL) e o Aprendizado baseado em Projetos (Project Based Learning - PjBL). Mas também, nota-se que muitos dos artigos não especificam qual estratégia ativa de aprendizagem está sendo relatada ou então descrevem sobre EAA's de uma forma geral. A estratégia PBL foi descrita em 54 artigos; a Pjbl foram 21 artigos; a Blended Learning foi 1 artigos; a Inquiry Based Learning foi 1 artigo, a P2BL foram 2 artigos; a In-class Exercise Teams foi 1 artigo; a PLE (Project-Led Education) foi 1 artigo e a P3BL foi 1 artigo. Como pode ser observado na Figura 2.

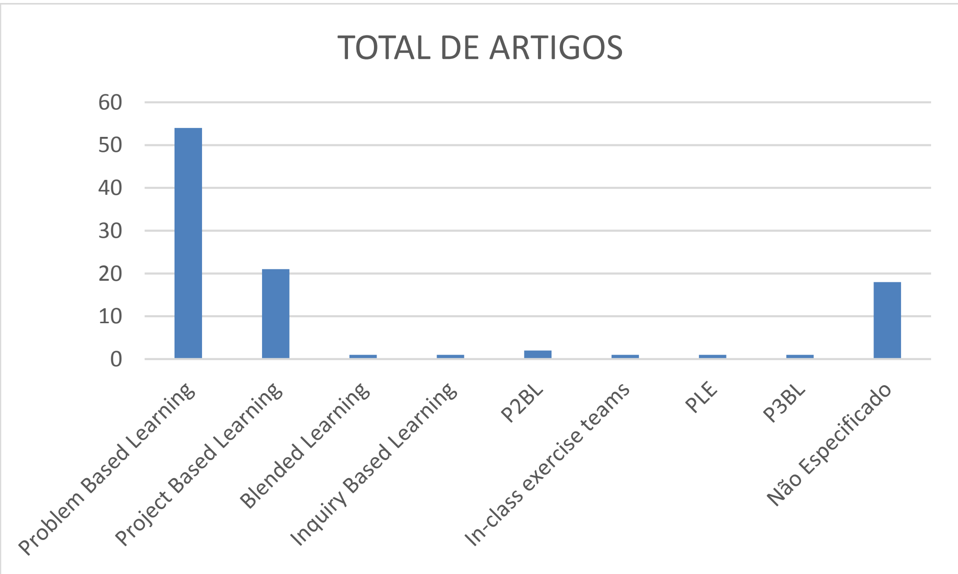

Figura 2: Gráfico de total de artigos por EAA

Uma informação relevante da pesquisa é saber quais Instituições de Ensino Superior (IES) mais relatam sua experiência sobre EAA's no COBENGE. Percebe-se que a Universidade Estadual de Feira de Santana com 14 artigos publicados durante os 8 anos pesquisados é a que mais descreve sobre EAA, seguida da Universidade de Brasília com 8 artigos, posteriormente vem a Universidade Federal de Juiz de Fora com 7 artigos e a Universidade de São Paulo com 5 artigos. Tal informação está demonstrada em gráfico na Figura 3.

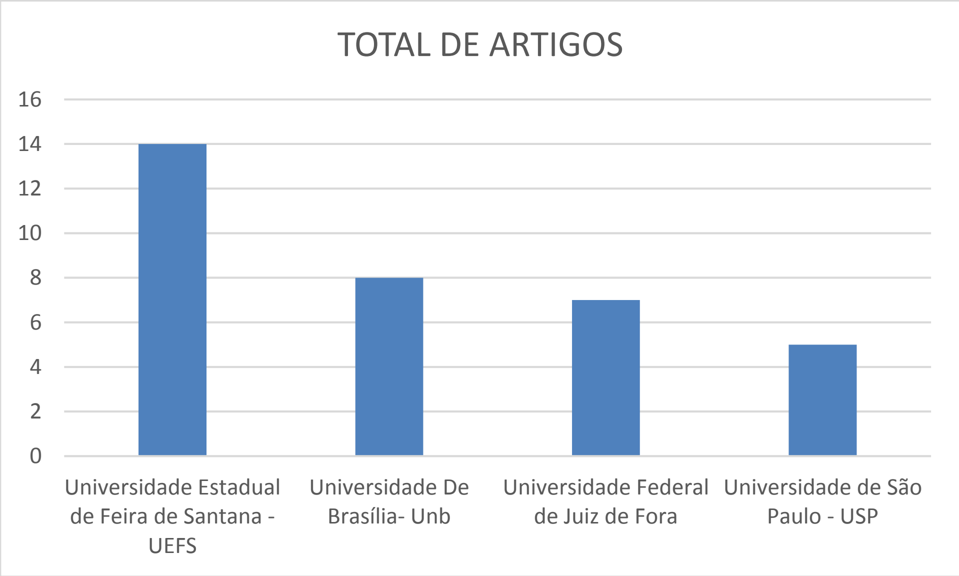

Figura 3: Gráfico de total de artigos por IES

É importante observar que foram 43 IES que contribuíram para o COBENGE da seguinte forma: CEFET-RJ com 1 artigo; a Instituição de Ensino Superior Pública do Estado de São Paulo com 1 artigo; a Universidade Federal do Rio Grande do Sul com 2 artigos; a Universidade do Vale do Rio dos Sinos com 1 artigo; a Universidade de Caxias do Sul com 3 artigos; a Universidade Federal Do Pará com 4 artigos; a Universidade Federal da Bahia com 3 artigos; o Serviço Nacional de Aprendizagem Industrial com 1 artigo; a Universidade Federal do Ceará com 1 artigo; a Universidade Federal Fluminense– RJ com 1 artigo; a Universidade Federal de Viçosa- MG com 1 artigo; a Faculdade de Tecnologia de Taquaritinga – FATEC/CEETEPS com 1 artigo; o Instituto Superior Tupy com 1 artigo; a Universidade Cruzeiro do Sul com 1 artigo; a Faculdade de Tecnologia de Tatuí com 4 artigos; a Universidade Paulista de Sorocaba com 1 artigo; a Universidade Gama Filho com 1 artigo; a Universidade Presbiteriana Mackenzie com 1 artigo; a Universidade Federal de Itajubá 2 artigos; a Universidade Federal do Espírito Santo 1 artigo; o Centro Universitário Salesiano de São Paulo (UNISAL) com 3 artigos; a Universidade Anhanguera com 1 artigo; o Instituto Federal de Educação, Ciência e Tecnologia da Bahia-IFBA com 1 artigo; a Universidade Federal de Goiás com 1 artigo; a Universidade Federal do Rio Grande do Norte com 3 artigos; o Centro Universitário SENAC com 1 artigo; o Centro Universitário do Instituto Mauá de Tecnologia com 2 artigos; a Universidade Federal de Alagoas com 1 artigo; o Instituto Federal de Educação, Ciência e Tecnologia da Paraíba-IFPB com 2 artigos; a Universidade do Estado de Santa Catarina com 1 artigo; a Universidade Tecnológica Federal do Paraná com 2 artigos; a Universidade de Ribeirão Preto com 1 artigo; a Universidade Federal do ABC com 1 artigo; a Escola de Engenharia de Lorena com 1 artigo; a Universidade Metodista de Piracicaba com 1 artigo; a Universidade Federal de São Carlos com 2 artigos; a Universidade Federal de Itajubá com 2 artigos; a Universidade Regional de Blumenau com 1 artigo; a Universidade Federal de Santa Maria com 1 artigo e 3 artigos não especificaram qual a sua IES.

Os cursos que mais descrevem sobre EAA são o de Engenharia de Computação e o de Engenharia Elétrica cada um com 18 artigos publicados. Na Figura 4 é possível observar quais outros cursos publicaram sobre EAA.

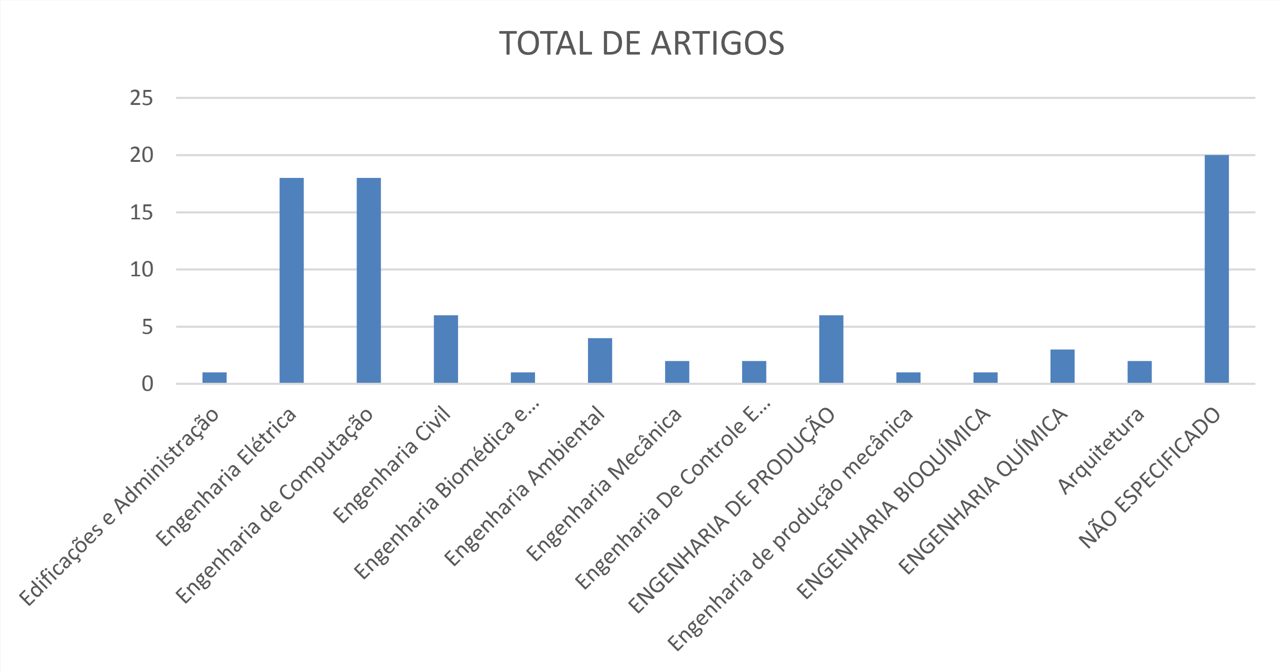

Figura 4: Gráfico de total de artigos por Curso

Os artigos selecionados foram categorizados para extrair a informação dos objetivos de cada artigo. Além disso, entender a motivação de uma maneira geral de todos os artigos selecionados. Observa-se que a maioria dos artigos selecionados descrevem a aplicação de estratégias ativas de aprendizagem no ensino superior, como pode ser observado na Tabela 1. Os artigos podem estar inseridos em mais de uma categoria.

Tabela 1: Quadro de Categorias

Categoria	Descrição	Observações	Total de Artigos
01	Aplicação das Estratégias Ativas de Aprendizagem no Ensino Superior	Artigos que apresentam experiências, estudos de caso, aplicações das estratégias ativas de aprendizagem no ensino superior.	71
02	Aplicação das Estratégias Ativas de Aprendizagem no Ensino Médio e Fundamental	Artigos que apresentam experiências, estudos de caso, aplicações das estratégias ativas de aprendizagem no ensino médio e fundamental.	4
03	Produção de Recursos Educacionais para Estratégias Ativas	Produção de AVAs, Objetos Educacionais e outros, voltados para a aplicação das estratégias ativas.	3
04	Avaliação das Estratégias ou do Uso das Estratégias	Artigos que fazem algum tipo de avaliação do uso das estratégias.	23
05	Fundamentos Teóricos de Estratégias Ativas de Aprendizagem	Artigos que abordem a parte de fundamentos teóricos das estratégias.	7

06	Formação de Professores e Estudantes para o uso de Estratégias Ativas de Aprendizagem	Artigos que tratam de preparação de pessoas para o uso das estratégias.	1
07	Revisão de Literatura	Artigos que realizem estudos de revisão de literatura e mapeamentos sistemáticos sobre as estratégias ativas.	4
08	Outros	Artigos que não se relacionam aos itens anteriores deverão ser identificados como Outros.	7

5 Conclusão

O artigo apresentou de forma sistemática o levantamento de artigos publicados entre 2007 e 2014 no Congresso Brasileiro de Educação em Engenharia mostrando dados importantes para o fomento da discussão sobre o uso estratégias ativas de aprendizagem na educação em Engenharia no Brasil. Para a sistematização das informações foi necessário fazer o estudo teórico sobre Mapeamento Sistemático, de forma que houvesse um maior rigor metodológico na pesquisa. As informações extraídas foram colocadas em gráficos e, no caso das categorias, num quadro.

Pretende-se ainda como trabalho futuro verificar a relação entre os cursos e as estratégias ativas de aprendizagem; os motivos que levam às IES a adotarem tais estratégias; as vantagens e desvantagens do uso das EAA's; verificar se as IES brasileiras que fazem uso das EAA's estão publicando no COBENGE; levantar as possíveis causas de não participação no COBENGE por parte das IES que utilizam alguma EAA; ampliar o estudo para outros eventos importantes sobre EAA, como o Active Learning in Engineering Education Workshop, o International Symposium on Project Approaches in Engineering Education.

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Analysis of Visual Tools for Project Management in PBL teams

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Abstract

The Integrated Project of Industrial Engineering and Management II (IPIEM2) course, of the 7th semester of the Integrated Master in Industrial Engineering and Management (IEM) at the University of Minho, uses a Project-Based Learning approach. In this course, students work in teams to find a solution for real problems of industry. In these solutions, students' teams articulate theory and practice, based on a set of interdisciplinary knowledge. Each team use and adapt different visual tools of Project Management, which can be studied in order to understand their relation to the learning model. The Project Management is not a technical objective of this project, so the students do not have classes or formal technical support from professors. Therefore, in order to support students in this management process, the project coordinator took the decision to give an initial class about some essential concepts in a Project planning visual tool, and asked the students to submit the project plan using this tool. The aim of this study is to analyse the use of visual tools for project management developed by students' teams of IPIEM2. The data collection is based on the study of five PBL teams, centred in teamwork and communication management as dimensions of analysis. During the semester, each team was free to choose the project management methodology. A periodically monitoring meeting was held in which the tutor could check the used resources, the positive and negative points, the progress of the project, and the perception of the teams about their work. It was observed that each team used the project management concepts in a different way, either using different tools, or improving and searching for new tools. One of the teams did not use any form of explicit management. It was possible to analyse the use of visual tools and verify benefits and disadvantages of their use in the context described above.

Keywords: Visual Tools; Project Management; Team Management; Communication Management.

Análise de Ferramentas Visuais para Gestão de Projetos em Equipas PBL

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Resumo

O Projeto Integrado do curso de Engenharia e Gestão Industrial II (PIEGI2), do 7º semestre do Mestrado Integrado em Engenharia e Gestão Industrial (MIEGI) da Universidade do Minho, utiliza uma abordagem de Aprendizagem Baseada em Projeto. Neste curso, os alunos trabalham em equipa com o intuito de encontrar uma solução para problemas reais de uma indústria. Nestas soluções, as equipas de alunos articulam teoria e prática, com base em um conjunto de conhecimentos interdisciplinares. Cada equipa usa e adapta diferentes ferramentas visuais de Gestão de Projetos, os quais podem ser estudados a fim de compreender sua relação com o modelo de aprendizagem. A Gestão de Projetos não é um objetivo técnico deste projeto, visto que os alunos não têm aulas ou suporte técnico formal professores. Portanto, a fim de apoiar os alunos no processo de gestão, o coordenador do projeto tomou a decisão de dar uma aula inicial sobre alguns conceitos essenciais ferramenta visual planeamento de projeto, e solicitou aos alunos que apresentassem o plano de projeto utilizando esta ferramenta. O objetivo deste estudo é analisar o uso de ferramentas visuais para a gestão de projetos desenvolvidos por equipas de alunos de PIEGI2. A coleta de dados baseia-se no estudo de 5 equipas PBL, centrado no trabalho em equipa e gestão da comunicação como dimensões de análise. Durante o semestre, cada equipa era livre para escolher a metodologia de gestão de projeto. Foram realizados encontros periódicos de monitoração, nos quais o tutor pode verificar os recursos utilizados, os pontos positivos e negativos, o progresso do projeto, e a percepção das equipas sobre o seu trabalho. Observou-se que cada equipa utilizou os conceitos de gestão de projetos de uma forma diferente, seja usando ferramentas distintas, ou aprimorando as existentes e buscando novas ferramentas. Uma das equipes não utilizou qualquer forma de gestão explícita. Foi possível analisar o uso de ferramentas visuais e verificar os benefícios e desvantagens de sua utilização no contexto acima descrito.

Palavras Chave: Ferramentas Visuais; Gestão de Projetos; Gestão de Equipas; Gestão da Comunicação; PBL.

1 Introdução

O cenário mundial atual é dinâmico, desafiador e altamente competitivo, envolvendo novos paradigmas econômicos e sociais, nos quais se encontram inerentes os princípios da sustentabilidade. As mudanças na sociedade, indústria e serviços demandam novos requisitos e melhores práticas, exigindo, assim, dos profissionais a capacidade de mobilizar todos os seus conhecimentos, habilidades para a solução de diversos tipos de problemas em um curto espaço de tempo, e que sejam capazes de se adaptarem a situações inconstantes, diferentes e desconhecidas. Este contexto influencia, de forma expressiva, a prática do profissional de Engenharia (Lima et al., 2011; Lima et al., 2012).

Porém, há uma distância entre a formação em engenharia e as competências exigidas pelo mercado de trabalho (indústria de bens e serviços) e pela sociedade. A UNESCO (2010:32) afirma que: "University courses can be made more interesting through the transformation of curricula and pedagogy using such information and experience in more activity - project and problem-based learning, just-in-time approaches and hands-on application, and less formulaic approaches that turn students off. In short, relevance works! (…) The future of the world is in the hands of young engineers and we need to give them as much help as we can in facing the challenges of the future". Có e Farias Filho (2007), enfatizam que a situação atual cobra uma resposta imediata das universidades, tornando claro que o mundo acadêmico precisa não só formar os seus alunos, mas criar situações de aprendizagem que os conduzam a desafios cada vez mais complexos, fazendo com que os aprendizes validem seus conhecimentos e habilidades através da experimentação de situações, criando esquemas mentais novos e mais elevados.
Para cumprir com este objetivo, a Educação em Engenharia vem tomando novo formato, acompanhando estas mudanças, lançando mão de novas técnicas, métodos e objetos de aprendizagem com objetivo de estimular os alunos e assim desenvolver as competências necessárias para sua formação.

Aquere, Mesquita, Lima, Monteiro, & Zindel (2012) afirmam que os novos modelos de ensino e aprendizagem, implicam a coordenação de equipes de estudantes para o desenvolvimento das competências necessárias e que a coordenação de equipes de estudantes baseados em problemas ou projetos demandam novos papéis para os professores e alunos, incluindo a necessidade de maior autonomia, integração de conteúdo interdisciplinar e trabalho em equipe. A reconfiguração do papel do professor tem mudado o foco do processo de ensino/aprendizagem para o desenvolvimento de atividades relacionadas com os alunos como por exemplo as tutorias que conduzem a um relacionamento mais próximo entre professor e aluno. Desta forma, o professor deixa de ser transmissor de informação e conhecimento, e o aluno passa também a ter um papel ativo na busca desse conhecimento. Nestes contextos, os estudantes são capazes de desenvolver competências essenciais à sua prática profissional (Lima, Mesquita e Rocha, 2013; van Hattum e Mesquita, 2011; Lima, Mesquita e Flores, 2014).

A Aprendizagem Baseada em Projetos interdisciplinares (PBL – Project-Based Learning) é uma das metodologias de ensino-aprendizagem que vem sendo adotada pelas escolas de engenharia, e que vêm contribuindo para auxiliar as universidades a responderem ao desafio de mudarem as suas práticas. O PBL, visa promover a aprendizagem através da participação dos estudantes na procura de soluções para problemas complexos (Graaff & Kolmos, 2003; Powell & Weenk, 2003; Lima et al., 2011). Além disso, um projeto reúne tanto aspectos teóricos, quanto práticos, e particularmente, os projetos interdisciplinares, auxiliam a tornar o processo ensino e aprendizagem mais atrativo, impulsionando os alunos à exploração de novas ideias e descobrirem novas formas de aplicar os conceitos adquiridos em sala de aula, desenvolvendo a capacidade de elaboração de hipóteses, investigando soluções, tirando conclusões e estabelecendo relações entre os diversos conteúdos assimilados.

Os conceitos de Gestão de Projetos podem ser aplicados em contextos PBL, como apoio ao desenvolvimento dos projetos, quer por parte dos alunos (Aquere et al, 2012), quer por parte dos professores (Lima et al., 2012). Nomeadamente para os alunos, a Gestão de Projetos, enquanto área consolidada e central na prática de engenharia, traz um contributo muito importante, na medida em que permite o desenvolvimento de competências como liderança, comunicação e trabalho em equipe. Tais competências, estão atreladas, particularmente, ao desenvolvimento de atividades relacionadas às áreas de conhecimento de Gestão de Equipas (RH) e a Gestão de Comunicação (PMI-PMBOK, 2013).

Por sua vez, os projetos interdisciplinares devem contemplar a divisão dos alunos em equipes suficientemente grandes para que seja possível exigir algum nível de complexidade, possibilitando a verificação do desenvolvimento tanto das competências técnicas como as transversais, através da aplicação de técnicas, ferramentas que possibilitam a Gestão eficaz e eficiente dos projetos.

A proposta de ensino/aprendizagem do Mestrado Integrado em Engenharia e Gestão Industrial (MIEGI) tem incidência em modelos de Aprendizagem Baseada em Projetos Interdisciplinares (PBL – "Project Based Learning"), e foi inspirada na proposta de Project Led Education - PLE (Powell, 2004; Powell & Weenk, 2003). Os alunos da Unidade Curricular (UC) Projeto Integrado de Engenharia e Gestão Industrial II (PIEGI II), por não terem em sua grade curricular a disciplina de Gestão de Projetos, necessitam de um apoio mais direcionado em relação a este aspecto. Tendo em vista a complexidade e responsabilidade do projeto a ser realizado, os alunos necessitam de analisar as questões da pesquisa em si e a organização do processo de desenvolvimento do mesmo. Assim, à medida que o projeto avança, cada equipa começa a identificar as responsabilidades de cada um e consequentemente, os alunos, começam a assumir ativamente seus papéis, resultando na realização das tarefas que culminarão no cumprimento dos objetivos propostos.

Neste sentido, o objetivo deste artigo consiste na análise do uso de ferramentas visuais nas diversas formas de gestão de equipas e de comunicação utilizadas pelas equipas do PIEGI II, durante todo o processo de desenvolvimento do projeto.

2 Contexto do Estudo

Este estudo enquadra-se no âmbito da UC PIEGI II, do 1º semestre do 4º ano do MIEGI da Universidade do Minho (UMinho), Portugal. Neste contexto, os alunos desenvolvem um conjunto de competências esperadas nesse semestre, através da realização de um projeto interdisciplinar que visa a análise, diagnóstico e identificação de propostas de melhoria para o sistema de produção de uma empresa. Estas propostas de melhoria têm que ser convenientemente justificadas, de acordo com critérios de avaliação definidos no desenrolar do processo.

No projeto do 4º ano – 1º semestre participam 6 Unidades Curriculares (UC) de apoio direto ao projeto: "Organização de Sistemas de Produção 2 (OSP2)", "Gestão Integrada da Produção" (GIP), "Sistemas de Informação para a produção" (SIP), "Simulação" (SIM), "Estudo Ergonómico de Postos de Trabalho" (EEPT), e "Projeto Integrado em Engenharia e Gestão Industrial 2" (PIEGI2). Os alunos foram divididos em 5 equipas, contendo 6 a 7 alunos em cada. Cada equipa trabalhou em uma empresa diferente, são elas: Bosch, Vishay, Rembalcom, Continental ITA, e Leoni.

As principais dificuldades sentidas pelos alunos durante o processo relacionam-se, sobretudo, com a gestão do projeto e o relacionamento interpessoal (Fernandes et al, 2014; Fernandes, 2011, Campos et al, 2012). Ao nível da gestão do projeto, os grandes desafios concentram-se na coordenação de horários, no cumprimento de prazos e na organização e planeamento das tarefas do projeto. Ao nível do relacionamento interpessoal, os principais desafios passam por aprender a gerir situações de conflito possivelmente causadas pela divergência de opiniões e ideias, pelo confronto de posturas e de atitudes, pela divergência dos objetivos individuais e pela falta de comunicação dentro do grupo. Estas dificuldades, que naturalmente acontecem durante a concretização do projeto, exigem estratégias para as ultrapassar. Entender estas dificuldades como desafios e saber como superá-los pode constituir um momento importante de aprendizagem.

A comunicação dentro de uma equipa de projeto é um dos pontos mais importantes e cruciais. Uma informação não recebida no momento certo, incorreta, mal interpretada, passada à pessoa errada, ou não disponível para auxiliar em uma tomada de decisão e até na execução de uma tarefa por um determinado membro da equipa, pode levar ao fracasso do projeto. Portanto, as organizações têm investido na busca por uma gestão de equipa e de comunicação eficazes, buscando reduzir os desperdícios, tanto de tempo como de custos e recursos, e assim, aumentando a produtividade. Para isso tem investido na Gestão Visual para os projetos, contemplando todas as áreas de conhecimento, porém, o trabalho aqui descrito tem o foco na Gestão de Equipas e de Comunicação.

A Gestão Visual surge como uma ferramenta eficaz no sentido de dinamizar o processo de comunicação dos membros de uma equipa, bem como da equipa de trabalho com os *stakeholders* do projeto. Facilita também a gestão de recursos humanos, já que os papéis, funções, atividades, cronogramas e andamento do projeto, dentre outros, estão disponíveis a todos em uma linguagem clara e acessível. Para Hall (2003), a comunicação de forma visual, possibilita a transmissão de informação através de uma linguagem acessível e simples a todos aqueles que tem acesso a ela. De modo a facilitar o trabalho e melhorar a qualidade das atividades. Diferentemente da comunicação verbal que é direcionada a alguém ou a um público específico, a comunicação visual tende a deixar a informação completamente inteligível a qualquer um que tenha acesso a ela.

Como exemplo da utilização da Gestão Visual para a Gestão da Comunicação em equipas de projetos pode-se ressaltar o Project Model Canvas (PMCanvas), ferramenta para desenvolvimento do Project Charter, utilizada no âmbito do estudo em questão. Com o intuito de formular uma abordagem de Gestão de Projetos mais adequada ao processo de cognição do ser humano, utilizando ferramentas que vão além das burocracias de documentos lineares, extensos e pouco compreensíveis, Finocchio (2013) desenvolveu o PMCanvas. O autor utiliza como base para seu modelo conceitos de neurociência e busca auxiliar gestores de projetos a construir um plano de projeto que se distancie da linearidade textual, que deixe claro as conexões entre as partes do projeto, mais simples de elaborar e efetivamente aplicável ao cotidiano.

3 Metodologia

Considerando o objetivo deste estudo, a abordagem metodológica assenta numa natureza descritiva-exploratória, que se caracteriza pela relação existente entre a teoria e a prática, mais utilizadas em contextos organizacionais (Gil, 2010). Tal tipo de investigação é realizado em especial em condições onde o tema escolhido é pouco explorado e portanto havendo uma dificuldade de formular hipóteses precisas e operacionalizáveis sobre ele. O produto desta etapa é um entendimento mais claro sobre o problema, tornando-o passível de investigação mediante procedimentos sistematizados (Gil, 2010).

Assim, optou-se por instrumentos de recolha de dados de caráter qualitativo, pela necessidade de lidar com informações não mensuráveis durante o processo de recolha de dados, para a obtenção de um conhecimento mais aprofundado sobre o assunto. O tipo de metodologia foi de Estudo de Caso, no qual a população estudada foi o conjunto de 5 equipas de alunos envolvidas na unidade curricular PIEGI II. Atribui-se aos Estudos de Caso a vantagem das múltiplas fontes de evidência para solucionar problemas de pesquisa que ressaltam o "como" e o "porquê".

A Gestão de Projetos não é encontrada de maneira formal e estruturada no contexto do PIEGI II, tendo em vista que os alunos não têm aulas nem apoio técnico formal, deste conteúdo, por parte de professores ligados ao PIEGI II. Contudo, a Gestão de Projetos é uma das competências esperadas que sejam desenvolvidas em equipas de projetos interdisciplinares, bem como adquirida por profissionais Engenharia e Gestão Industrial, nomeadamente a Gestão de Equipas e de Comunicação. Sendo assim, com o objetivo de apoiar os alunos neste processo de gestão, foi realizada uma intervenção, a partir de uma aula inicial sobre conceitos essenciais de gestão de projetos, particularmente a gestão de equipas e de comunicações. Além disso o PMCanvas, ferramenta de Gestão Visual, descrita anteriormente, também teve seus conceitos, vantagens e forma de utilização passados aos alunos, para que fosse possível desenvolver o Project Charter e dar início ao planeamento do projeto.

Para um completo entendimento do trabalho que os alunos iriam realizar, de forma a obter informações suficientes para organizar as ações da pesquisa aqui contemplada, foi necessário realizar um estudo da documentação do Projeto Integrado, bem como dos *milestones* e resultados a serem desenvolvidos pelos alunos. Também foi necessário compreender o campo de atuação e características de cada uma das empresas parceiras do projeto, através de análise documental e, sempre que possível, através de visitas às empresas com os alunos.

Após as visitas dos alunos às empresas, o primeiro resultado foi o Project Charter. Foi então realizado um acompanhamento com tutoria em Gestão de Projetos, no qual foram sanadas dúvidas dos alunos, bem como novas orientações foram dadas, aperfeiçoando a compreensão deles sobre a ferramenta e os objetivos desta entrega.

No contexto da realização deste trabalho de investigação realizou-se um acompanhamento estruturado do andamento dos projetos das equipas. O objetivo desse acompanhamento era perceber seus avanços e dificuldades quanto à gestão da equipa e do processo de comunicação realizado, bem como suas necessidades ou não quanto à utilização de novas técnicas e ferramentas de gestão de projetos para facilitar e melhorar estas interações. Todas as técnicas e ferramentas, bem como alterações inseridas ao longo do processo de gestão do projeto foram avaliados, e feedbacks foram realizados. Cada equipa foi acompanhada individualmente e todas as dúvidas deles, feedbacks dados e resultados semanais foram devidamente anotados em um "diário de bordo", para posterior cruzamento e análise dos dados.

Nos seminários de apresentação de andamento do projeto, em datas previamente definidas, houve acompanhamento sem intervenção, onde foram observadas apenas as apresentações e anotados no diário de bordo os comentários e sugestões dos professores avaliadores, para que fosse possível posteriormente verificar como a comunicação e a integração da equipa pode influenciar nos resultados apresentados e nas críticas, elogios e sugestões dados.

Em determinado momento, aproximadamente a meio do semestre letivo, foi realizada uma reunião com cada equipa, na qual responderam a questões e houve uma discussão sobre as expectativas, contributos e resultados da tutoria e intervenções da gestão de projetos sobre o andamento dos projetos. O objetivo foi obter um feedback sobre o trabalho realizado e verificar possibilidades de melhorias imediatas nas atividades e intervenções, bem como planejar e aperfeiçoar o trabalho em projetos futuros, visando a aprendizagem mais eficaz e eficiente pelos alunos.

No final do projeto dos alunos foi realizada a análise documental do relatório final dos alunos, no que se refere ao tópico Gestão de Projetos, e foi realizado o acompanhamento da apresentação do seminário final com a apresentação dos resultados dos projetos.

Foi realizado um workshop com o objetivo de auscultar as opiniões e percepções dos alunos acerca da experiência que tiveram, considerando os aspetos positivos, aqueles que tinham de ser melhorados e ainda propostas de sugestões de melhoria. Este workshop foi precedido por um questionário. Neste workshop ainda houve a oportunidade de discutir algumas questões relacionadas com a gestão de projetos. Após a aplicação deste questionário algumas questões foram colocadas aos alunos.

Posteriormente foi realizada a Análise dos Dados através da triangulação dos mesmos, visto que um conjunto diverso de técnicas de recolha de dados foi utilizado, permitindo, assim, a sistematização e convergência da informação. Isso, para tornar a análise dos dados mais precisa e integrada, contribuindo para validar a pesquisa (Denzin, 1994; Yin, 1995).

4 Resultados

Considerando a informação recolhida ao longo do semestre foi possível analisar o uso das técnicas e ferramentas das Gestão de Projetos utilizadas, particularmente as de gestão de equipa e de comunicação, de modo a verificar vantagens e desvantagens de sua utilização no contexto descrito, além de se ter a percepção da relação existente entre sua utilização e a obtenção de melhores resultados.

Para a descrição dos resultados obtidos foram tomados como parâmetros, as técnicas e ferramentas utilizadas na Gestão de Projetos, dentro dos grupos de processos Iniciação, Planeamento, Monitoração, Controlo e Encerramento, referentes às áreas de conhecimento de Gestão de Equipa (Recursos Humanos) e de Comunicação.

A análise e discussão dos resultados da investigação foram divididas em três partes. Primeiramente fez-se uma análise global, com o objetivo de analisar, em uma visão de todas as equipas, a aplicação de conceitos e utilização de técnicas e ferramentas de Gestão de projetos (equipa e comunicação); em um segundo momento, fez-se um estudo sobre a prática da implementação destes itens em duas equipas, aquela que teve mais sucesso e aquela que obteve menos sucesso; e finalmente fez-se uma discussão crítica destes resultados.

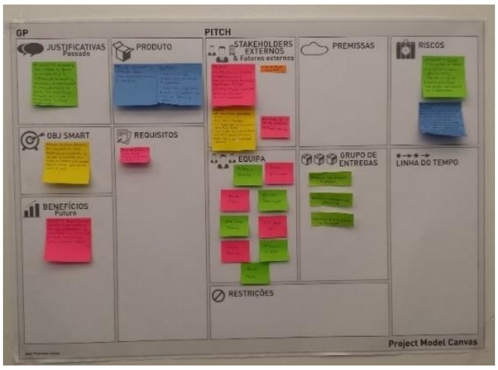
4.1 Análise Global

Todas as equipas utilizaram de alguma forma conceitos de Gestão de Projetos, explicitamente ou não. Isso acontece porque na prática as equipas têm que realizar um projeto, cumprindo com todas as etapas requeridas, e por isso terão que efetuar a gestão das atividades mesmo que de forma intuitiva. Para que pudessem prosseguir com as tarefas, sentiram a necessidade de conhecer as partes interessadas (stakeholders), bem como definir funções e dividir tarefas dentro da equipa e em cada etapa.

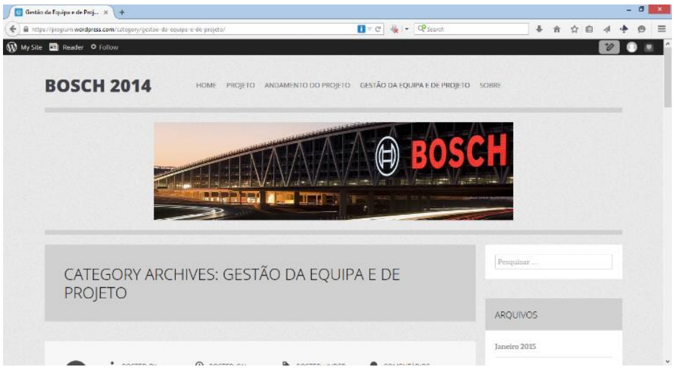
Em todas as equipas existiram conflitos e houve necessidade de os resolver, mesmo que precariamente. Algumas equipas buscaram orientação para gerir estes problemas e conseguiram superar as dificuldades e outras fracassaram na sua gestão, mesmo com oportunidade de ter apoio especializado.

As dúvidas das equipas sempre estiveram registadas de alguma maneira, porém, nem sempre visualmente. Os organogramas, a definição de funções dentro da equipa, a divisão de tarefas, o estudo das partes interessadas, utilização de tecnologias para a comunicação entre os membros e a busca por opinião especializada são exemplos destas técnicas e ferramentas utilizadas. Foi assim possível verificar evidências de desenvolvimento de competências de Gestão de Projetos ao longo do projeto.

O PM Canvas foi uma ferramenta apresentada e sugerida durante a fase inicial do projeto, e todas as equipas a utilizaram como ferramenta de Gestão Visual, por ser um dos resultados do projeto. Porém, a maioria das equipas não manteve o quadro atualizado perdendo algum do seu potencial de apoio à gestão do projeto ao longo do tempo. Já o blog, foi utilizado como ferramenta de comunicação, gestão da equipa e monitoramento do trabalho realizado, embora a sua utilização não tenha sido muito constante ao longo do projeto para algumas das equipas. Estas foram as duas únicas ferramentas visuais de utilização obrigatória na avaliação geral das atividades do projeto (Figura 1).



(a)



(b)

Figura 1: Exemplos de PMCanvas (a) e Blog (b) das equipas.

4.2 Estudo de equipas com mais e com menos dificuldades de implementação

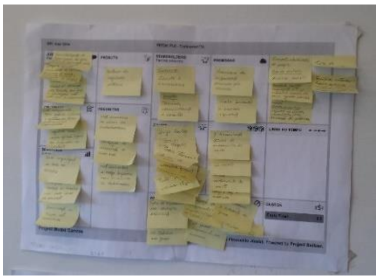
É importante, primeiramente, caracterizar cada uma das duas equipas destacadas, justificando a escolha das mesmas para terem seus resultados apresentados neste artigo: A Equipa Z (designação anónima) utilizou, no início, como gestão visual apenas o Project Charter, tiveram muitas dificuldades em termos de comunicação e de relacionamento entre os membros da equipa, e posteriormente tentaram resolver as dificuldades com a aplicação da gestão visual, desenvolvendo um conjunto de elementos de gestão como numa *obeya-room*, sala de guerra. Porém não obtiveram sucesso com a gestão da equipa e da comunicação. Já a Equipa Y (designação anónima) desenvolveu uma *obeya-room* desde o início do projeto, onde várias ferramentas de gestão visual foram contempladas à medida que o projeto caminhava. Foram escolhidas, portanto, por terem características completamente diferentes, e pelos distintos desenvolvimentos e desempenhos durante o projeto.

A Equipa Z teve muitos problemas na relação interpessoal, e uma difícil comunicação. Inicialmente desenvolveram o Project Charter, contendo o planeamento inicial do projeto, e para isso utilizaram a ferramenta visual PMCanvas. Porém, após uma melhor avaliação do que a empresa pretendia, fizeram alterações e com o passar do tempo o Project Charter ficou desatualizado e não fizeram qualquer alteração. Quanto à Gestão da Equipa, eles definiram suas atividades, dividiram-se em subequipas e designaram as tarefas por subequipas. As subequipas trabalhavam individualmente e em nenhum momento reuniam-se para transmitir as informações adquiridas e resultados conquistados para os demais membros da equipa, acarretando em dificuldades de integração e de troca de conhecimentos. Na parede da sala haviam frases de incentivo, porém isso era feito de maneira fria. Utilizavam um quadro de dúvidas, divido por assunto, para as sanarem com os professores especialistas de cada área envolvida no projeto. Além disso, não desenvolveram qualquer tipo de controle de tempo, assim postergavam a realização das atividades.

Com apoio de tutoria em GP, que realizou uma intervenção sobre Gestão Visual como apoio à comunicação e trabalho em equipa, onde foram abordadas as vantagens de utilização e algumas ferramentas, a equipa sentiu-se motivada a mudar. Fizeram as alterações que julgaram necessárias, receberam novamente a tutoria que identificou a utilização das ferramentas: Controlo de Atividades a partir de um Plano de Trabalho Semanal, usando uma ferramenta de Kanbans de tarefas (dividido por subequipas), com post-its de cores diferentes para cada equipa; usaram mais frases de incentivo, utilizando cores para dar destaque. Já havia então um quadro de funções da equipa, e começaram a marcar as reuniões da equipa para falar sobre as realizações semanais de tarefas. O quadro de dúvidas passou a ter outra subdivisão contendo as dúvidas relacionadas à empresa. Também foi feito um diagrama de Gantt para as tarefas relacionadas à uma das UCs que demandava maior detalhamento de atividades. Também foi feito um quadro com a Linha do tempo, enfatizando a precedência das atividades, com o uso de post-its. Montando assim o que se pode considerar uma sala de controlo do projeto.

Contudo, apesar de sentirem-se motivados, e terem desenvolvido vários elementos de apoio à gestão do projeto, não os colocaram em prática. A desmotivação inicial e falta de controle do gestor, e as características particulares dos membros da equipa, como a falta de pró-atividade, baixo relacionamento interpessoal da maioria dos integrantes, o individualismo, e falta de liderança, contribuíram para que nada do que foi desenvolvido para a gestão tenha sido colocado em prática.

Apesar de entenderem e concordarem com as vantagens da utilização de técnicas e ferramentas de gestão de projetos e de ferramentas visuais para apoiar a gestão da comunicação e da equipa, concluíram que isso tudo não pode funcionar se não for utilizado da forma correta. Um ponto principal que a equipa chamou atenção, foi a má relação entre os membros, a falta de pró-atividade e de liderança.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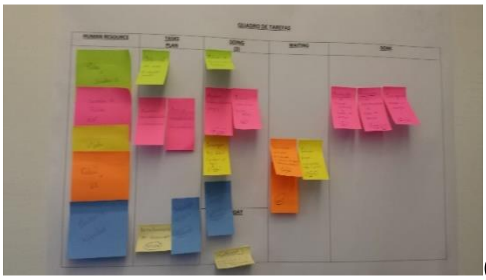
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Figura 2: Ilustração de utilização de PMCanvas (a) e de Quadro de Kanbans de Tarefas por Subequipas (b).

A Equipa Y teve um bom relacionamento interpessoal, e os que não tinham entrosamento, o adquiriram. Inicialmente desenvolveram o planeamento inicial do projeto, assim como as demais equipas, utilizando a ferramenta visual PMCanvas. Após visitas à empresa, identificaram necessidades de alterações no âmbito que haviam definido no Project Charter, mantendo o documento atualizado à medida que fosse necessário. Assim conseguiam ter informações corretas e atualizadas a respeito do projeto que estavam desenvolvendo. À medida que o projeto caminhava, a equipa adquiria novos conhecimentos por sua pró-atividade.

Quanto à Gestão da Equipa, eles definiram organogramas, cargos e tarefas, as quais foram divididas por subequipas, de acordo com cada UC envolvida. Tinham um quadro de dúvidas, no qual as subequipas inseriam as dúvidas que surgiam durante o trabalho, para as sanarem com o restante da equipa, com os professores especialistas ou na própria empresa. A cada semana havia uma reunião onde todos explanavam sobre seus avanços da semana e faziam uma troca de informações sobre o que aprenderam e sobre suas dificuldades, dando oportunidade para que os demais pudessem opinar e sugerir soluções e até mesmo críticas construtivas ao seu trabalho. Os alunos desta equipa buscaram incentivar uns aos outros, ajudavam-se mutuamente e partilhavam todo o aprendizado. Desta forma, era possível identificar o desempenho e a produtividade das pessoas ao longo de cada semana.

Tiveram bom desempenho na gestão de conflitos pois conseguiram identificar um integrante que poderia realizar bem este papel, o que foi fundamental para a equipa manter-se em equilíbrio. Eles definiram regras básicas para o trabalho e comunicação, e seguiam um Plano de Trabalho, que ficava exposto para todos. Assim, cada um sabia o que o outro estava realizando e era possível ver a relação de sua tarefa com as demais, além disso conseguiam prever o que ainda havia a se fazer, saber o que estava faltando ser realizado, facilitava a gestão e a tomada de decisão.

As ferramentas que introduziam a cada semana foi fruto de sua pró-atividade. Sentiam a necessidade, buscavam auxílio especializado, aprendiam e implementavam. A tutoria em Gestão de Projetos semanalmente buscava auxiliá-los nas melhorias e validava a implementação e utilização das ferramentas. Uma das ferramentas que desenvolveram foi o "Quadro de Avanços". Neste quadro inseriam as atividades realizadas semanalmente que acrescentavam valor ao relatório que que fazia parte dos resultados do projeto.

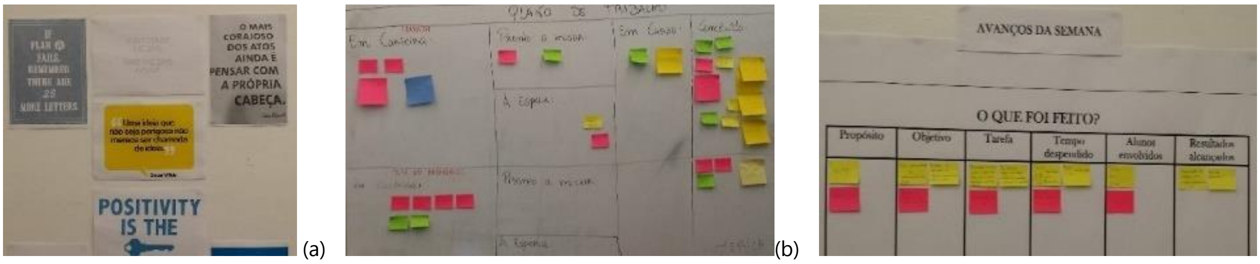

Figura 3: Equipa Y - Frases de incentivo e funções (a) Quadro de Kanbans de Tarefas (b) Avanços da Semana (c)

4.3 Discussão Crítica

Neste trabalho, foi possível perceber que as equipas utilizaram a Gestão de Projetos de alguma forma, e que implementaram a gestão visual. Foi possível perceber que tiveram um bom rendimento em relação às suas atividades de projeto, no que diz respeito à clareza da comunicação, capacidade de previsão, melhoria na tomada de decisão, evolução do trabalho realizado, integração entre as partes do projeto, bem como as pendências existentes.

Observou-se que cada equipa trabalhou a gestão do projeto de uma forma diferente, utilizando ferramentas distintas, aprimorando e buscando novas ferramentas, ou ainda não utilizando qualquer forma de gestão explícita. Os resultados foram distintos em todas as equipas. Além disso, obtiveram bons resultados na interação, integração, avançando no projeto com uma visão de equipa, pois concentraram-se em um objetivo comum, sem individualismo. Estas equipas conseguiram alcançar o objetivo, e desenvolveram as competências em Gestão de Projetos. Algumas mais do que as outras, devido à intensidade com que se envolveram na busca por técnicas e ferramentas mais eficazes para auxiliá-las na gestão. Entretanto, aquelas equipas que usaram a gestão visual mas não internalizaram os conceitos e não esforçaram-se para mudar, alcançaram resultados, mas não desenvolveram todas as capacidades esperadas de Gestão de Projetos. Ainda houve aquelas que desenvolveram as competências, mesmo sem utilizar a Gestão Visual, pelo fato de serem equipas organizadas, centradas, com um líder capaz de gerir o processo, em especial as comunicações e a equipa, utilizando as ferramentas tradicionais de Gestão de Projetos. Isso tudo deve-se ao fato de que a Gestão de Projetos é uma disciplina de boas práticas, ou seja, em qualquer projeto sentimos a necessidade de usá-la, a partir de ações naturais. Porém, o que faz a diferença no sentido de eficácia, é a utilização de Técnicas e Ferramentas adequadas para gerir da melhor maneira possível.

O fato de deixar os alunos livres para decidirem sobre a forma de gerir o projeto e os métodos para tal tem vantagens e desvantagens. Por um lado os alunos constroem seu conhecimento a respeito dos elementos necessários para o desenvolvimento do projeto, por outro lado eles podem ou não utilizar determinados elementos que tornariam o processo mais eficaz e aumentaria a produtividade.

5 Conclusão

Os conceitos de Gestão de Projetos podem ser aplicados em contextos PBL tanto pelos alunos, nas práticas diárias do projeto, quanto pelos professores, na gestão dos projetos de alunos (Lima et al, 2011). A Gestão de Projetos traz um contributo muito importante, à medida em que permite o desenvolvimento de competências associadas à esta área, tais como liderança, comunicação e trabalho em equipa. Tais competências, estão atreladas, particularmente, ao desenvolvimento de atividades relacionadas à Gestão de Equipas (RH) e a Gestão de Comunicação (Aquere et al, 2012). As ferramentas de Gestão Visual dinamizam o processo de comunicação dentro de uma equipa, e melhora também este processo com os demais envolvidos no projeto. A gestão da equipa também é facilitada, pois os papéis, funções, atividades, cronogramas, avanços e controle do projeto, dentre outros, ficam disponíveis a todos em uma linguagem clara e acessível. Desta forma o trabalho é otimizado e aumenta a qualidade das atividades realizadas.

Em relação ao contributo das intervenções de Gestão de Projetos, de forma geral, do ponto de vista dos alunos, pode-se dizer que obtiveram sucesso, principalmente àquelas equipas onde a Gestão Visual predominou. Os alunos afirmaram que as ferramentas visuais auxiliaram em sua organização enquanto equipa, na organização do trabalho a ser realizado, os motivaram em ter a visão das tarefas concluídas, e que a intervenção inicial foi fator preponderante para que pudessem ter uma orientação para iniciar as tarefas. Ainda, afirmaram que o conhecimento e desenvolvimento das competências em Gestão de Projetos ajudou-os a prepararem-se para um ambiente empresarial onde há predominância de desenvolvimento de projetos, e tem a consciência de que o conhecimento destes princípios é essencial para sua formação. Quanto à tutoria de Gestão de Projetos, alguns grupos afirmaram que achavam extremamente necessário, já outros afirmaram que conseguiriam avançar sem ela, devido ao perfil de cada equipa, considerando a pró-atividade e a real necessidade do ponto de vista da utilização do que estava sendo proposto. Há melhorias a serem realizadas, que foram detectadas através de entrevistas com as equipas e questionários empregados individualmente. A intervenção inicial precisa ser melhorada, em questão de conteúdo e motivação para se utilizar os conceitos de Gestão de Projetos e as ferramentas de Gestão Visual. Algumas alterações foram sugeridas, como a inclusão, na intervenção inicial, de ferramentas de equipas anteriores que obtiveram sucesso na utilização. O contributo seria a transmissão aos alunos dos resultados positivos na implementação, e assim motivando-os e mostrando as vantagens de utilização para desenvolvimento de seu perfil profissional.

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Mapping of a civil engineering course for project identification in the curriculum proposal

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Abstract

The objective of this paper is to present the mapping of the current civil engineering course at the Escola de Engenharia Mauá - EEM as the use of projects by specific disciplines, namely, those who is content is directly related to enabling civil engineering. This research is justified because the school is in a Curricular reform process and meet the current course as to its curriculum structure can help in the decision of a more or less comprehensive change towards the new pedagogical project, in this case, approaching the Project based methodology Learning - PjBL, since the course's policy is to use projects. Thus, this study looked at the use of projects in disciplines or group of disciplines and, if so, how projects are currently structured, it is interdisciplinary, whether they are developed horizontally in the same series of the course, or vertically in series subsequent course and also how the planning of these projects are and what learning outcomes. For the study was done using documentary analysis of teaching plans of specific disciplines, representing the formal curriculum, use of questionnaire applied to all teachers and interview with the coordinator of the course. The results of the literature indicate that the use of project aligns with the desired professional profile for civil engineer, having as benefits the development of soft skills such as teamwork, pro-activity and responsibility; systemic view; project management skills and better understanding of the theory and practice relationship, making the acquired significant knowledge. Course mapping found that already makes use projects in EEM and a relevant observation about the opinions of teachers is that learning varies with the involvement of students or projects and work teams, getting more or less satisfactory results.

Keywords: Projects, Multidisciplinary, Civil Engineering, Project Based Learning.

Mapeamento de um curso de Engenharia Civil para identificação de projetos na proposta curricular

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Abstract

O objetivo deste trabalho é apresentar o mapeamento do atual curso de engenharia civil da Escola de Engenharia Mauá – EEM quanto a utilização de projetos pelas disciplinas específicas, ou seja, aquelas cujo conteúdo está diretamente ligado a habilitação Engenharia Civil. Esta pesquisa se justifica porque a Escola está num processo de Reforma Curricular e conhecer o curso atual quanto à sua estrutura curricular pode ajudar na decisão de uma mudança mais ou menos abrangente, rumo ao novo projeto pedagógico, no caso, se aproximar da metodologia *Project Based Learning – PjBL*, já que o curso tem como diretriz a utilização de projetos. Assim, este estudo buscou verificar a utilização de projetos em disciplinas, ou conjunto de disciplinas e, em caso afirmativo, como os projetos estão estruturados atualmente, se são interdisciplinares, se são desenvolvidos horizontalmente, numa mesma série do curso, ou verticalmente, em séries subsequentes do curso e, ainda, como é feito o planejamento destes projetos e quais os resultados de aprendizagem obtidos. Para o estudo fez-se o uso de análise documental dos planos de ensino das disciplinas específicas, que representa o currículo formal, uso de questionário aplicado a todos os docentes e entrevista com a coordenadora do curso. Os resultados da pesquisa bibliográfica indicam que o uso de projetos se alinha ao perfil profissional desejável para o engenheiro civil, possuindo como benefícios o desenvolvimento de habilidades transversais, tais como: trabalho em equipe, proatividade e responsabilidade; visão sistêmica; noções de gestão de projetos e melhor entendimento da relação teoria e prática, tornando o conhecimento adquirido significativo. O mapeamento do curso constatou que já se faz uso de projetos na EEM e uma observação relevante quanto a opinião dos professores é que a aprendizagem varia de acordo com o envolvimento entre projetos e alunos ou equipes de trabalho, obtendo resultados mais ou menos satisfatórios.

Palavras chaves: Projetos, Multidisciplinaridade, Engenharia Civil, Project Based Learning.

1 Introdução

A Escola de Engenharia Mauá - EEM está passando por um processo de Reforma Curricular e conhecer a situação atual do curso quanto à sua estrutura curricular pode auxiliar na decisão de uma mudança mais ou menos abrangente rumo ao novo projeto pedagógico, que busca implementar o *Project Based Learning - PjBL*.

O objetivo deste trabalho é mapear o atual curso de engenharia civil da EEM. Esse mapeamento se dará buscando identificar quais disciplinas específicas, ou seja, aquelas cujo conteúdo está diretamente ligado a habilitação engenharia civil, desenvolvem projetos. Além desta identificação, outro fator a ser verificado é quanto a relação entre as disciplinas que desenvolvem projetos, se há uma relação vertical, entre séries subsequentes, ou horizontal, entre disciplinas de mesma série do curso, ou ambos ou, ainda, se é caracterizada como unidisciplinar, ou seja, o projeto independe de outras disciplinas.

Como a escola busca adotar metodologias ativas de ensino, também foi foco deste levantamento, a identificação de outras atividades que possam auxiliar o aluno a ser mais ativo, como: aulas práticas de laboratório, palestras, seminários, debates, estudos de caso, questionários e outros mecanismos.

Uma fonte de dados importante, foi a percepção da coordenadora do curso de engenharia civil, que pode indicar o interesse em encaminhar o curso em direção a proposta com base em *PjBL*, o que ela visualiza como o futuro do curso e como planeja fazer essa reforma curricular.

2 Revisão Bibliográfica

Metodologias ativas são aquelas cujo aprendizado está centrado no aluno, que assume a corresponsabilidade pelo aprendizado passando a exercer um papel ativo, portanto o professor passa a ser um tutor com papel de facilitador, que tem como função estimular, motivar, provocar e questionar os estudantes, deixando de ser o único detentor e transmissor do conhecimento. Nessa concepção tanto habilidades não técnicas como as técnicas, são desenvolvidas.

2.1 Estrutura do PjBL

Inicialmente buscou-se entender como é a estrutura da metodologia *Project Based Learning – PjB*L (Silveira et al., 2008), que é a seguinte:

1. Fornecer/escolher o tema do projeto.
2. Coletar fatos: entender o projeto proposto (pesquisa inicial), formular os problemas envolvidos e estabelecer os objetivos do trabalho.
3. Criar ideias para resolver ou elaborar o projeto.
4. Aprender os conteúdos necessários para a realização do projeto/produto.
5. Discussão das propostas de solução e realização do trabalho, sua viabilidade e chega-se a uma solução a ser implantada.
6. Elaboração e implementação do projeto/produto.
7. Realização de testes, coletando dados e verificando os resultados obtidos.
8. Elaboração de um relatório escrito e de um seminário (apresentação oral) contendo: o objetivo, a descrição do projeto, a metodologia aplicada, os resultados e análises realizadas e, por fim, a conclusão do grupo com relação ao trabalho.

Algumas das vantagens na utilização do *PjBL* são:

- Aprende-se a buscar ferramentas e metodologias para solucionar problemas e elaborar projetos (Villas-Boas, V. et al, 2012; Rezende Júnior, 2013).

- Interdisciplinaridade e entendimento da relação entre o conteúdo teórico e a prática (Silveira, 2008; Pereira; Araújo, 2011; Torres, 2011; Corrêa, 2013).

- Visão do trabalho do engenheiro e aquisição de consciência de responsabilidade econômica, social e ambiental (Silveira, 2008; Villas-Boas, V. et al, 2012; Neves, 2013).

- Melhor fixação de conhecimentos e ativação dos conhecimentos prévios (Neves, 2008; Pereira; Araújo, 2011; Corrêa, 2013).

- Responsabilidade pela própria aprendizagem e automotivação para aprender (Neves, 2008; Pereira; Araújo, 2011; Corrêa, 2013).

- Desenvolvimento de habilidades transversais (liderança, trabalho em equipe, comunicação, solução de conflitos, desenvolvimento de visão sistêmica, gestão de projetos e conhecimento multidisciplinar) (Silveira, 2008; Neves, 2013; Torre, 2011; Corrêa, 2013).

3 Metodologia

3.1 Análise documental – Planos de ensino das disciplinas

A primeira etapa foi de análise documental de todos os planos de ensino das disciplinas específicas do curso de engenharia civil da EEM, afim de identificar quais disciplinas desenvolviam projetos ou trabalhavam com atividades diferentes de aulas teóricas expositivas, como por exemplo: aulas práticas de laboratório, debates, estudos de caso e visitas técnicas a obras. Além disso, buscou-se verificar se havia indícios de utilização de metodologias ativas. Foram analisados no total 37 planos de ensino, que se encontram a disposição dos alunos no site da faculdade (www.maua.br) na área restrita aos alunos.

Foi elaborado um questionário para os docentes das disciplinas em estudo, com o intuito de verificar se as informações descritas no plano de ensino estavam de acordo com o que os professores realizavam efetivamente em sala de aula. Os questionários tinham como objetivo complementar as informações que estavam sendo estudadas, para se obter mais dados sobre as disciplinas.

A distribuição dos questionários aconteceu da seguinte forma: um questionário por professor e por disciplina. Se um professor trabalhava com quatro disciplinas, recebeu quatro questionários, para responder sobre cada uma das disciplinas; para disciplinas com mais de um professor, foi distribuído um questionário por docente. Optou-se por esta forma e não somente se ter a resposta do professor responsável pela disciplina, porque algumas disciplinas têm duas frentes de trabalho, e enquanto um professor desenvolve a teoria, outro trabalha aulas de laboratório e exercícios ou, então, numa mesma disciplina, cada um trabalha uma parte do conteúdo independentemente do outro. Um segundo motivo foi para que pudesse comparar as informações dadas pelos professores de uma mesma disciplina, averiguando se eles estão alinhados em quanto a metodologias e conteúdo, nos casos de disciplinas em que professores trabalham em conjunto.

3.2 Entrevista com a coordenadora do curso de engenharia civil do EEM

O curso de engenharia civil da EEM está passando por uma reforma curricular, e este trabalho visa auxiliar esse processo, foi utilizada a ferramenta de entrevista, para identificar quais as pretensões na realização da reforma curricular do curso de engenharia civil. Utilizou-se o mecanismo de entrevista, porque ele é um instrumento mais aberto, quer dizer, não limita as respostas, sendo assim, um meio de obter informações mais completas e esclarecer melhor pontos de interesse.

A entrevista com a coordenadora do curso de engenharia civil da EEM, foi realizada no dia 19 de novembro de 2014, com o objetivo de identificar os rumos que ela pretende dar ao curso nos próximos anos, e se a reforma curricular visa se aproximar mais ou menos de uma metodologia de aprendizagem baseada em projetos (*Project Based Learning – PjBL*) e quais as alterações já previstas para o ano letivo de 2015, bem como para os anos posteriores.

4 Dados e Resultados

4.1 Plano de Ensino das disciplinas específicas do curso

Analisando os planos de ensino das 37 disciplinas específicas do curso de engenharia civil da EEM, pode-se verificar que 15 matérias declaram oficialmente desenvolver projetos em suas aulas, sendo que 8 delas pertencem ao quarto ano da graduação. Além de projetos, foi possível observar que outras atividades utilizadas como meios de ensino são: visitas técnicas à obra, estudos de caso, debates, aulas de exercícios, aulas laboratoriais, aulas assistidas por programas de computador, trabalhos em equipe e seminários.

4.2 Análise das respostas obtidas por meio do questionário

Ao todo foram entregues 47 questionários, sendo que retornaram e foram analisados 29. Os professores podiam optar por responder ou não o questionário.

Quadro 1 – Distribuição de questionários respondidos e analisados por série

Ano de graduação (Série)	Disciplinas específicas oferecidas	Disciplinas que responderam o questionário	Professores que responderam o questionário
2º	5	5	7
3º	7	7	8
4º	10	4	5
5º	7	5	5
Eletivas	8	4	4
Total	37	25	29

Essa distribuição permite avaliar como estão distribuídos os projetos dentro no curso de engenharia civil da EEM.

Os resultados obtidos por meio da análise das respostas do questionário elaborado e respondido pelos docentes da EEM estão descritos no Quadro 2. Começando pela quantificação e distribuição dos projetos no curso de engenharia civil.

Quadro 2 – Distribuição de projetos de acordo com os anos de graduação

Ano de graduação (Série)	Disciplinas específicas oferecidas	Disciplinas que responderam o questionário	Disciplinas que utilizam projetos	Professores que responderam o questionário	Professores que desenvolvem projetos
2º	5	5	4	7	5
3º	7	7	4	8	4
4º	10	4	4	5	5
5º	7	5	4	5	4
Eletivas	8	4	2	4	2
Total	37	25	18	29	20

Como se pode observar, os projetos estão bem distribuídos em todos os anos de graduação, e foram analisadas 68% das disciplinas oferecidas pelo curso, e destas 72% fazem uso de projetos em suas aulas.

De acordo com as respostas do questionário, 9 disciplinas realizam trabalhos interdisciplinares, sendo que apenas uma trabalha com disciplinas do mesmo ano de graduação, relação horizontal de interação, 4 com disciplinas de anos distintos de graduação, interação vertical entre as matérias e 4 declararam que trabalham com projetos interdisciplinares verticais e horizontais.

Destaca-se que na relação interdisciplinar vertical, a EEM possui um projeto denominado Projeto Integrador, que consiste em um mesmo projeto base que se inicia no 2º ano de graduação e é utilizado por disciplinas do 3º e 4º ano, cujo objetivo é fazer os alunos irem desenvolvendo os conceitos específicos de cada disciplina numa mesma planta de edificação, com o intuito dos alunos perceberem as relações entre as diferentes disciplinas e as dificuldades existentes para que se faça a compatibilização desses projetos. Apesar do Projeto Integrador envolver diferentes disciplinas, constatou-se que os diferentes professores não se relacionam entre si, cada professor planeja sua disciplina sem consultar seus colegas. Já as disciplinas que possuem mais de um professor lecionando a mesma matéria, eles realizam o planejamento anual em conjunto, e todo ano trocam experiências e alinham os conteúdos, para que os alunos adquiram os mesmos conhecimentos.

A duração dos trabalhos desenvolvidos varia entre meio bimestre (1 mês) e 4 bimestres, sendo que a maioria tem duração de 4 bimestres, ou seja, um ano letivo completo. Os projetos são desenvolvidos com acompanhamento do professor, exceto em 2 disciplinas, e o atendimento as dúvidas dos alunos ou grupo de alunos a respeito dos projetos e atividades a serem desenvolvidas, é feito de diversas formas, são elas:

- Apenas durante o horário de aula: 3 disciplinas;
- Apenas fora do horário de aula: 7 disciplinas;
- Durante o horário de aula e fora do horário de aula: 9 disciplinas;
- Fora do horário de aula pelo professor ou aluno monitor: 3 disciplinas;
- Durante o horário de aula e fora do horário de aula pelo professor e aluno monitor: 2 disciplinas.

As principais formas de avaliação dos trabalhos se dá das seguintes formas:

- Por etapas: 17 disciplinas;
- Em uma única etapa – ao final do trabalho: 8 disciplinas;
- Relatório escrito: 15 disciplinas;

- Apresentação oral: 6 disciplinas;

- Participação dos alunos durante as aulas ou durante os trabalhos: 6 disciplinas;

- Outros (questionários, planilhas, croquis, maquetes, memorial de cálculo): 7 disciplinas.

Como o objetivo da pesquisa busca analisar a estrutura curricular atual do curso de engenharia civil da EEM, buscou-se conhecer se os docentes utilizam outras ferramentas de ensino para envolver o aluno e ensiná-lo, com exceção do uso da metodologia tradicional de ensino, que são as aulas teóricas expositivas, pois busca-se instrumentos que auxiliem os alunos a se tornarem mais ativos e ajudá-los a entender a relação entre a teoria dada em aula e o dia-a-dia de um profissional de engenharia civil. O resultado foi a utilização das seguintes ferramentas:

- Visitas técnicas às obras: 9 disciplinas;

- Exercícios desenvolvidos em sala de aula: 8 disciplinas;

- Palestras: 6 disciplinas;

- Seminários: 5 disciplinas;

- Utilização de softwares de computador como apoio: 5 disciplinas;

- Aulas práticas em laboratório: 4 disciplinas;

- Lista de exercícios: 4 disciplinas;

- Estudos de caso e debates em grupo: 4 disciplinas.

A justificativa para a utilização dos instrumentos de ensino citados acima e para a utilização da metodologia ativa *PjBL*, são que com o método tradicional os professores não conseguem desenvolver nos alunos algumas habilidades e, com o uso dessas outras técnicas de ensino conseguem obter as seguintes melhorias:

- O aluno visualiza melhor a relação entre os trabalhos desenvolvidos e as situações reais vivenciadas cotidianamente pelo profissional engenheiro civil;

- O estudante associa melhor os conceitos teóricos com a prática, facilitando seu aprendizado e melhorando a fixação dos conceitos dados em aula;

- Os alunos se envolvem mais com a disciplina, ou seja, tornam-se mais participativos e promove uma melhor integração entre o estudante e o professor;

- Desenvolve a criatividade do aluno para obter soluções mais criativas e viáveis para os problemas propostos, além de torná-los mais responsáveis, resultando em valorização do aprendizado e formação de pessoas com espírito crítico;

- Desenvolve a capacidade de coordenar e ser coordenado, devido aos trabalhos em grupo;

- Estimula o interesse pela profissão;

- Como os alunos utilizam programas computacionais, isso o ajuda a ingressar no mercado de trabalho.

A única ressalva que os professores comentaram, é que como a maioria dos trabalhos é desenvolvido em equipes de 2 a 5 alunos, e que alguns estudantes não fazem nada e acabam por não alcançar esses benefícios descritos acima.

4.3 Entrevista com a coordenadora do curso de engenharia civil do EEM

A entrevista com a coordenadora do curso de engenharia civil, forneceu informações sobre a reforma curricular proposta para os próximos anos letivos, iniciando-se em janeiro de 2015.

As grandes mudanças se iniciarão no primeiro ano de graduação, pois a metodologia baseada em projetos necessita de alunos mais ativos, logo para se obter sucesso na implementação desse método é exigido que os alunos assumam uma postura diferente do habitual, de passividade, e para isso é necessário estimulá-los desde o início, desenvolvendo uma cultura de alunos ativos. Para alcançar esse objetivo foi criado dois novos projetos destinados aos alunos do primeiro ano, são eles:

- SimCity – aula com auxílio do aplicativo SimCity na qual os alunos irão construir uma cidade sustentável. O objetivo é fazer com que percebam a importância das disciplinas que virão nos anos subsequentes, tais como: topografia, geologia, teoria das estruturas e hidrologia.

- Ampliação do projeto já existente do primeiro ano, dentro da disciplina de Introdução à Engenharia Civil, que era um projeto de elaboração de maquete de uma edificação e ensaio da ação do vento sob essa construção em túnel de vento. A proposta de ampliação para 2015 é a de englobar outros aspectos importantes na elaboração de projetos de engenharia, por meio de elaboração de planilha de orçamento, dando uma visão mais completa do cenário da profissão.

Na visão da professora entrevistada, o curso de engenharia civil da EEM já está estruturado com base em projetos, então as modificações que irão ocorrer do segundo ao quinto ano, é a criação de duas categorias de projetos, os cotidianos e os especiais. O projeto cotidiano, será desenvolvido pelo aluno obrigatoriamente, ou seja, todos devem elaborá-lo, pois ele é considerado como parte da base necessária para se tornar um bom professional, ao contrário, os projetos especiais, serão atividades optativas, nos quais o aluno pode escolher de acordo com suas preferências, estes serão trabalhos mais específicos. Essa oportunidade de escolha possibilitará que o aluno pense antecipadamente qual área da engenharia civil pretende seguir, algo que antes da reforma curricular, o estudante só se preocupava em pensar no último ano do curso.

5 Conclusão

A partir da análise feita, pode-se concluir que os planos de ensino são bem simplificados, porém os professores seguem suas propostas curriculares, fazendo com que a utilização do questionário tenha sido uma ferramenta de complementação de informações, porque pode-se descobrir itens que não constavam nos planos de ensino, em compensação, a análise documental foi importante para mapear todas as disciplinas oferecidas no curso de engenharia civil, já que não foi possível obter as respostas do questionário de todo o corpo docente, ou seja, não se teve respostas sobre todas as disciplinas.

Por meio da entrevista com a coordenadora do curso de engenharia civil do EEM, pode-se perceber que ela realmente planeja estruturar o curso com base na metodologia ativa *Project Based Learning – PjBL*, iniciando as mudanças no ano letivo de 2015, e tendo como alterações a forma de distribuição das aulas, a criação de novos projetos dentro das disciplinas e do sistema de avaliação dos alunos.

Considerando todo o cenário descrito pela coordenadora do curso e da análise dos planos de ensino e das respostas dos docentes, percebeu-se que o curso atual já faz uso de projetos, no entanto, está se tentando modelar a estrutura mais parecida com a desenvolvida pela metodologia ativa *PjBL*, que se baseia totalmente em projetos, professores tutores e alunos ativos.

Apesar dos projetos realizados na EEM não estarem modelados com base no *PjBL*, pode-se constatar que algumas das principais vantagens citadas em artigos lidos para a elaboração da revisão bibliográfica sobre a metodologia ativa em estudo, foram alcançadas, sendo as principais: alunos que sabem trabalhar em equipe, responsáveis pelo seu próprio aprendizado e com senso crítico, habilidades que os tornam mais competitivos no mercado de trabalho. Sendo assim, a ideia é estruturar o curso em *PjBL*, efetivamente, afim de ampliar os benefícios da utilização de um aprendizado baseado em projetos.

Agradecimentos: A todos os professores que gentilmente responderam os questionários e a entrevista.

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Evaluation tools in disciplines that use the Project Based Learning

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Abstract

The aim of this work is to present the results of a study on types of evaluation of learning in disciplines that use the projects model in Project Based Learning structure - PjBL. For this study was taken basis in the course in Civil Engineering offered by the School of Engenharia Mauá – EEM, considering for analysis only the specific subject offered by the course. The data collection process was done by reading the course outline of the subjects under study and the data obtained through a questionnaire answered by all teachers of disciplines that work with projects. The use of these two resources of obtaining data, aimed to get as close as possible to the information that is carried out on the course. Comparing the data, it was noted inconsistencies between what is stated in the course outline and teachers responses to the questionnaires. From the information of this research, you can assist in improving the valuation method used by teachers in order to improve the assessment of students, taking into account the complexity of the developed projects. In other words, considering both the content learned by the student, as well as other skills that he can develop with the completion of the work, for example: deal with different personalities of the team members, learn who to written works and forms of oral presentation and understand the application of theoretical concepts learned in the classroom, in practice. The assessment of student performance should consider this whole range of skills, it is the main difference in the use of PjBL active methodology in relation to traditional teaching methods. As a result of this study, we obtained that the main evaluation methods used by the teachers EEM is the written report and oral presentation in the form of seminars, most of which will evaluate the project only in the end. Thus, it is noted that there is need to expand, with the group of teachers, the perception of the wide possibility of what is valued.

Keywords: Evaluation; Project-Based Learning; Civil Engineering

Instrumentos de Avaliação de aprendizagem em disciplinas que utilizam o Project Based Learning

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Abstract

O objetivo deste trabalho é apresentar os resultados de um estudo quanto aos tipos de avaliação de aprendizagem em disciplinas que fazem uso de projetos modelados na estrutura Project Based Learning – PjBL. Para a realização deste estudo, tomou-se como base o curso de Engenharia Civil oferecido pela Escola de Engenharia Mauá - EEM, considerando para análise apenas as disciplinas específicas oferecidas pelo curso. O processo de levantamento de dados se deu pela leitura dos planos de ensino das disciplinas em estudo e dos dados obtidas através de um questionário respondido por todos os professores das disciplinas que trabalham com projetos. A utilização desses dois meios de obtenção de dados, teve como objetivo buscar informações o mais próximo possível do que é realizado efetivamente no curso. Confrontando os dados, notou-se inconsistências entre o que está declarado nos planos de ensino e as respostas dos professores aos questionários. A partir das informações desta pesquisa, será possível auxiliar no aprimoramento do método de avaliação utilizado pelos docentes, visando melhorar a avaliação dos estudantes, levando em consideração a complexidade dos projetos desenvolvidos, ou seja, considerar tanto o conteúdo aprendido pelo aluno, como também outras habilidades que ele possa desenvolver com a realização do trabalho, como por exemplo: lidar com as diferentes personalidades dos integrantes da equipe, aprender a redigir trabalhos escritos e formas de apresentação oral e entender a aplicação dos conceitos teóricos, trabalhados em sala de aula, na prática. A avaliação do desempenho do estudante deve considerar toda essa amplitude de habilidades, pois é o principal diferencial no uso da metodologia ativa PjBL em relação as metodologias tradicionais de ensino. Como resultado deste estudo, obteve-se que os principais métodos de avaliação usados pelos docentes da EEM é o relatório escrito e a apresentação oral em forma de seminários, sendo que a maioria avalia os trabalhos apenas no término do projeto. Dessa forma, nota-se que há necessidade de ampliar, junto ao grupo de professores, a percepção da ampla possibilidade do que é avaliar.

Keywords: Avaliação; Project-Based Learning; Engenharia Civil

1 Introdução

O objetivo deste trabalho é estudar e analisar a forma e o modo como os professores avaliam seus alunos em disciplinas que utilizam projetos no curso de Engenharia Civil da Escola de Engenharia Mauá. Trata-se de um levantamento, que visa identificar os instrumentos de avaliação relacionados com as estratégias de trabalhos com os estudantes e as habilidades que são avaliadas, além dos conteúdos das disciplinas.

A justificativa é que conhecer essa relação entre os instrumentos de avaliação e as estratégias de ensino podem contribuir para aprimorar o curso e também contribuir para manter os planos de ensino das disciplinas atualizados. Um trabalho como este tem muitas variáveis a serem estudas, o que requer uma análise minuciosa dos dados.

Tomou-se como referência estudos realizados em outras faculdades, que tiveram êxito no seu modelo de aprendizagem baseada em projetos, com dados que tornam foi possível montar um planejamento para uma futura alteração no curso de Engenharia Civil na EEM, no sentido de torna-lo também um curso com base em Projetos.

2 Revisão Bibliográfica

Na Pontifícia Universidade Católica do Paraná - PUC-PR o uso de projetos integradores no curso de engenharia de computação, permitiu que o curso passasse a empregar critérios de avaliação individualizados, mesmo em trabalhos desenvolvidos em equipe. Neste sentido, 75% da nota é individual, atribuída pelo cumprimento de metas em reuniões semanais. Outros 25% serão obtidos pela avaliação global da equipe em projeto. Não realizando provas teóricas.

A avaliação semanal, pelo professor coordenador consta em:

- Pontualidade na entrega do trabalho solicitado.
- Organização do trabalho desenvolvido.
- Qualidade e coerência na apresentação.
- Correção do trabalho escrito.
- Avaliação das conclusões obtidas pelos alunos.

A experiência na condução das atividades mostra que a escolha de um professor coordenador também é um fator fundamental para o sucesso do projeto.

Um dos benefícios evidentes é o aprendizado prático. Ao se envolverem com projetos, os alunos enfrentam dificuldades e experimentam sucessos em áreas que dificilmente são cobertas por disciplinas acadêmicas. Outro resultado importante a destacar é o auxílio indireto no aprendizado do aluno em disciplinas que orbitam o projeto.

A questão da avaliação está diretamente associada às competências que o engenheiro deve ter, ao se considerar que competências transversais têm sido requisitadas nesses profissionais. Assim, a habilidade para o trabalho em equipe, capacidade de comunicação, dentre outras, como Lima, Mesquita & Rocha (2013), são competências desejadas nos futuro engenheiro e a avaliação da aprendizagem dessas competências devem ser realizadas, para garantir a eficácia do processo de aprendizagem.

Assim, ter um currículo que vá além daquele tradicional que se traduz em aulas expositivas e centrado no estudante (Krasilchik, 1987; Masetto, 2005), é a possibilidade de se promover uma formação inovadora e que forme o profissional que é atual. Nesse sentido estratégias ativas de aprendizagem, são o caminho para essa formação. Os projetos interdisciplinares têm sido cada vez mais utilizados na formação do engenheiro, sendo que uma das justificativas para isso é o fato de contribuir para diminuir as taxas de abandono; Para estimular a motivação para a aprendizagem; Para acentuar o perfil institucional; Para apoiar o desenvolvimento de novas competências (Kolmos &, De Graaff, 2007).

3 Metodologia

Para o estudo da avaliação realizadas nas disciplinas que utilizam Projetos foram analisados os planos de ensino das disciplinas específicas da Engenharia Civil da EEM e uma das questões de um questionário entregue aos professores com perguntas sobre trabalhos, provas, participação do aluno, constituição de nota em trabalhos entre outros. Cabe indicar que apenas uma questão foi utilizada, porque o questionário tinha um espectro de investigação maior, no entanto, apenas uma das questões estava diretamente relacionada à avaliação dos estudantes. A questão específica desse questionário, analisada para este trabalho, era relativa a avaliação:

O(s) projeto(s) ou essa(s) outra(s) atividade(s) é(são) avaliado(s) em etapas ou apenas no final do trabalho? Qual o método e os instrumentos de avaliação (apresentação, relatório escrito, maquete, outros.)?

As respostas a essa questão foram consideradas apenas para aquelas disciplinas que declararam que realizavam um trabalho por projeto, o que também foi detectado neste questionário por uma questão específica, "*Você desenvolve projetos com os estudantes na sua disciplina?*".

Junto a isso houve a análise documental do plano de ensino das disciplinas, nos quais constam dados sobre método de avaliação em projetos, proporção notas entre provas e trabalho dentre outros dados fundamentais para a execução do trabalho. Como esses dados coletados e analisados foi possível cruzar as informações e sobre a avaliação nas disciplinas que fazem uso de projetos no curso de Engenharia Civil da EEM.

No total foram analisados 29 planos de ensinos e 25 questionários preenchidos pelos professores, com questões foi possível analisar os métodos de avaliação para a correção de trabalho e projetos.

4 Dados e Resultados

Desta forma foi possível ter um parâmetro entre o que a instituição visa e como que os professores aplicam, onde houve divergência em algumas disciplinas. Geralmente nas disciplinas onde se explora mais a parte de exatas o método de avaliação se restringe ao uso de do método padrão de avaliação por provas. O Quadro 1 apresenta a resposta dos professores à questão sobre avaliação do trabalho por projeto no curso de Engenharia Civil da EEM.

Quadro 1 – Disciplinas e indicação da avaliação realizada nos projetos.

<table>
<tr><th>Ano</th><th>Disciplinas</th><th>Questão</th><th>Etapas</th><th>Final</th><th>Relatório</th><th>Seminário</th><th>Participação</th></tr>
<tr><td rowspan="4">2</td><td>Representações Gráficas</td><td>Trabalhos menores são avaliados em uma única etapa, já trabalhos maiores são desenvolvido em etapas com controle e avaliação parciais. (Apresentações e Maquetes)</td><td>Sim</td><td>Sim</td><td>--</td><td>Sim</td><td>--</td></tr>
<tr><td>Topo</td><td>Avaliação em etapas através de Planilhas e Croquis</td><td>Sim</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td>Resistencia dos Materiais 1</td><td>No final do trabalho</td><td>--</td><td>Sim</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td>Geologia</td><td>Avaliação em etapas através de apresentações e Relatórios Parciais</td><td>Sim</td><td>--</td><td>Sim</td><td>--</td><td>--</td></tr>
<tr><td rowspan="5">3</td><td>Resistencia dos Materiais 2</td><td>Final do trabalho</td><td>--</td><td>Sim</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td>Teoria Estrutura</td><td>Relatórios escritos avaliado no final</td><td>--</td><td>Sim</td><td>Sim</td><td>--</td><td>--</td></tr>
<tr><td>Fenômenos de transporte</td><td>Avaliação ocorre apenas no final e o instrumento de avaliação é o relatório escrito</td><td>--</td><td>Sim</td><td>Sim</td><td>--</td><td>--</td></tr>
<tr><td>Mec. Solos</td><td>Para cada ensaio realizado o aluno deverá entregar um relatório escrito</td><td>Sim</td><td>--</td><td>Sim</td><td>--</td><td>--</td></tr>
<tr><td>Construção de edifícios</td><td>Participação dos alunos, entrega dos projetos, seminários e participação em aula. Avaliação final.</td><td>--</td><td>Sim</td><td>--</td><td>Sim</td><td>Sim</td></tr>
<tr><td rowspan="4">4</td><td>Urbanismo</td><td>Feito em Etapas e com critérios (A avalição é feita pelos professor e pelos alunos)</td><td>Sim</td><td>--</td><td>--</td><td>--</td><td>Sim</td></tr>
<tr><td>Concreto 1</td><td>2 avaliações parciais e 2 finais no ano.</td><td>Sim</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td>Metálicas</td><td>Atividades são avaliadas só no final das atividades.</td><td>--</td><td>Sim</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td>Fundações</td><td>Atualmente por relatórios e peça de desenho com representações gráficas. Para 2015 existirão etapa intermediarias de avaliação ao longo do desenvolvimento.</td><td>--</td><td>Sim</td><td>Sim</td><td>--</td><td>--</td></tr>
<tr><td rowspan="2">5</td><td>Planejamentos</td><td>Alguns em etapas outros no final. Apresentações e relatórios escritos.</td><td>Sim</td><td>Sim</td><td>Sim</td><td>--</td><td>--</td></tr>
<tr><td>Pontes</td><td>Avaliação em etapa através de relatórios escritos e pranchas de desenho</td><td>Sim</td><td>--</td><td>Sim</td><td>--</td><td>--</td></tr>
<tr><td>Eletiva</td><td>Modelo Computacional Aplicada a Geotécnica</td><td>Final do trabalho. Relatório escrito e interação com os alunos durante o desenvolvimento.</td><td>--</td><td>Sim</td><td>Sim</td><td>--</td><td>--</td></tr>
<tr><td>Total</td><td>16 disciplinas</td><td></td><td>8</td><td>10</td><td>8</td><td>1</td><td>1</td></tr>
</table>

Por meio dos dados tabelados, foi possível verificar que a instituição busca o aprimoramento no tipo de ensino PjBL. Nas disciplinas que utilizam relatório como métodos de avaliação, são as matérias que focam sua avaliação na parte escrita dos alunos, já nas disciplinas que tem seminário como métodos de avalição focam suas avaliações na parte oral e nas de participação em aula focam a interação e comunicação entre o grupo, professores e outros alunos. Portanto existem elementos que indicam a tentativa de avaliação de habilidades transversais, o que pode aproximar o trabalho realizado da perspectiva de trabalho do Project Based Learning.

No caso de algumas matérias mais teóricas, é possível ver que a quantidade de trabalhos é maior, facilitando a analise visto que se realiza uma avaliação periódica e esporádica, da capacidade cognitivas dos alunos. Além disso os projetos auxiliam na compreensão pratica dos temas abordados nas respectivas matérias da Engenharia Civil.

Nos últimos anos a EEM tem trabalhado para transformar o ensino de Engenharia para o método americano/europeu, ou seja, fazer com que o ensino seja realizado através da prática de projetos na modalidade Project Based Learning – PjBL. Os dados para a análise foram e adicionados em uma tabela de Excel, cursando os dados entre planos de ensino e questionário dos professores.

5 Conclusão

Foi possível perceber que o método de avaliação varia entre tipos de disciplinas, tendo disciplinas práticas e teóricas necessitando mais atenção em projetos ou em provas. Além disso podemos concluir que o método da instituição tem se transformado ao longo dos últimos anos, visando a pratica na forma de projetos dinâmicos como seminário, relatórios e participação.

Atualmente a instituição visa o aprimoramento do modo de ensino para o modo PjBL, um modo mais dinâmico e cotidiano ao mercado de trabalho traves de projetos (seminário, relatórios entre outros).

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Evaluation of PBL based on the CIPP Model: findings from a case study.

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Abstract

This paper presents findings from a broader project aimed at the evaluation of a Project-based Learning (PBL) experience in the context of an Engineering course at the University of Minho. The study aimed to analyze the impact of PBL on student learning and its implications for teachers work. To carry out the evaluation, the CIPP - Context, Input, Process, Product - Evaluation Model (Stufflebeam, 2003), was used as a framework for evaluating the PBL approach in its various dimensions. This paper discusses the main conclusions reached with the evaluation of each of the CIPP dimensions, describing the methods used for collecting data and the analysis of results achieved, based on the theoretical assumptions which guided the research.

Keywords: evaluation; project-based learning; engineering education

O contributo do modelo CIPP para a avaliação de experiências de PBL: resultados de um estudo de caso.

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Abstract

Este artigo apresenta os resultados da avaliação de um estudo de caso baseado em experiências de PBL (*Project-based Learning)* no contexto do 1º ano de um curso de Engenharia na Universidade do Minho. Trata-se de um estudo no âmbito de um projeto de investigação mais vasto (Fernandes, 2011) que pretendeu analisar o impacto do PBL nos processos e nos resultados de aprendizagem dos alunos bem como as suas implicações ao nível do trabalho dos docentes. Para tal, foi utilizado o Modelo de Avaliação CIPP (*Context, Input, Process, Product*), de Stufflebeam (2003), como quadro de referência para a avaliação do dispositivo pedagógico nas suas várias dimensões. O artigo discute as principais conclusões obtidas em cada uma das dimensões do modelo CIPP, descrevendo as respetivas técnicas de recolha de dados e a interpretação dos resultados à luz dos pressupostos teóricos que nortearam a investigação.

Keywords: active learning; engineering education; symposium information; project approaches.

1 Introdução

A Aprendizagem baseada em Projetos ou *Project-based Learning* (PBL) representa um contributo significativo no alcance dos objetivos do processo de Bolonha, nomeadamente no que se refere aos processos de ensino e aprendizagem centrados na aprendizagem do estudante e ainda às mudanças desejáveis ao nível do trabalho dos docentes. A revisão da literatura nesta área (Albanese & Mitchell, 1993; Dochy *et al*., 2003; Savery, 2006), sobretudo, no contexto do ensino de Engenharia (Graaff & Kolmos, 2003; Bébard *et al*., 2007; Frenay *et al.,* 2007), dão conta de investigações e estudos nos quais se procura refletir sobre os contextos e condições favoráveis para uma aprendizagem mais ativa e significativa, destacando, por exemplo, a importância de criar ambientes de aprendizagem e de trabalho cooperativo, envolvendo equipas de professores e equipas de alunos, com responsabilidade partilhada e sentido de autonomia para gerir a sua própria aprendizagem e desenvolvimento pessoal.

2 Modelos de Avaliação

A revisão da literatura no campo da avaliação, sobretudo, no que diz respeito à avaliação de programas e de projetos de educação e formação, revela a existência de um conjunto de modelos, cujos processos de implementação remetem para diferentes conceções de avaliação, privilegiando lógicas e pressupostos também eles distintos. Assim, é possível encontrar abordagens centradas no entendimento da avaliação como um processo sistemático de recolha de informação útil para a tomada de decisões, nomeadamente, o Modelo de Avaliação CIPP, de Donald Stufflebeam (2003); abordagens centradas nas dimensões pragmática e instrumental, como a utilidade e temporalidade da avaliação, como o modelo ICP proposto por Gerard Figari (1996); ou abordagens centradas na verificação da qualidade de uma intervenção formativa, como o modelo de avaliação dos Resultados da Formação proposto por Donald Kirkpatrick, um dos modelos mais conhecidos e utlizados no campo da formação (Kirkpatrick & Kirkpatrick, 2005).

Em seguida, segue uma descrição mais pormenorizada do modelo de avaliação CIPP e as suas características, uma vez que este serviu de referencial teórico para o desenvolvimento e implementação do processo de avaliação no contexto em análise.

Modelo de Avaliação CIPP

Segundo Stufflebeam (2003), a avaliação consiste num processo mediante o qual se proporciona informação útil para a tomada de decisões. Trata-se de um processo contínuo, que inclui essencialmente três etapas - delinear, obter e fornecer informações úteis para a tomada de decisão. A avaliação serve, assim, de guia para a tomada de decisões, proporcionando dados para a prestação de contas e promovendo a compreensão dos fenómenos envolvidos.

Este modelo de avaliação, mais conhecido pelo acrónimo CIPP (*Context, Input, Process* e *Product*), estabelece como grandes domínios de análise o contexto, os *inputs* (entradas) da formação, o processo formativo e os produtos obtidos (Stufflebeam, 2003), a que correspondem diferentes processos de avaliação com implicações ao nível da tomada de decisão:

- A *Avaliação do Contexto*, que diz respeito às decisões de planeamento, de identificação de necessidades, oportunidades e problemas. Tem como finalidade a tomada de decisões de planificação;
- A *Avaliação das Entradas* (*Inputs*), que engloba a análise da adequação das estratégias previstas aos objetivos do projeto, com base na qual são tomadas decisões de estruturação;
- A *Avaliação do Processo*, que inclui as decisões de aplicação e implementação das estratégias previstas, orientando as operações do projeto;
- A *Avaliação do Produto* (*Outputs*), que compara os resultados obtidos com os objetivos previstos ou resultados esperados para o projeto, permitindo a tomada de decisões de revisão e melhoria.

Prevalece uma relação dinâmica entre os principais elementos-chave deste modelo e as dimensões de avaliação que lhes são correspondentes. Assim, a avaliação do contexto está centrada nos objetivos (*Goals*), a avaliação das entradas baseia-se nos planos (*Plans*), a avaliação do processo preocupa-se com as acções (*Actions*) e, por último, a avaliação do produto verifica os resultados (*Outcomes*) da implementação das ações.

3 Contexto do Estudo

Desde 2004/2005 que tem sido implementada a metodologia de ensino aprendizagem baseada em projectos - project-based learning, no primeiro ano do curso de Engenharia e Gestão Industrial (Mestrado Integrado) MIEGI, da Universidade do Minho, Portugal. Pretende-se que os alunos integrem os conteúdos das várias unidades curriculares num único projeto, que desenvolvem em grupo. Deste modo, os alunos têm a possibilidade de desenvolver, para além das competências específicas das áreas disciplinares, competências de integração entre estas áreas, e um conjunto de competências transversais, que constituem uma das mais valias do trabalho de projeto.

A organização do PBL está calendarizada em torno das 20 semanas que integram o semestre letivo (Lima, Carvalho, Sousa, Alves, Moreira, Mesquita, & Fernandes, 2012). No início do ano letivo, é constituída uma equipa de coordenação, que integra todos os docentes das unidades curriculares, tutores e investigadores da área da Educação, que prestam apoio pedagógico ao projeto. Esta equipa de coordenação reúne regularmente com o objetivo de discutir o progresso dos projetos e dos grupos e resolver atempadamente eventuais problemas que possam surgir. Os alunos são organizados em grupos de 6/7 elementos, constituindo, geralmente, um total de 6 grupos de trabalho por semestre. A cada grupo é atribuído um tutor, que monitoriza o desenvolvimento do projeto e o trabalho de grupo, servindo de elo de ligação entre o grupo e a equipa de coordenação do projeto (Fernandes & Flores, 2013).

A monitorização do processo de ensino e aprendizagem dos alunos é assegurada através do estabelecimento de vários Pontos de Controlo (*Milestones*) que têm um carácter sobretudo formativo, permitindo aos alunos obter *feedback* dos professores sobre o trabalho que estão a desenvolver. Estes pontos de controlo podem assumir diversas formas, desde apresentações formais, tutoriais alargados (reunião privada de cada grupo com toda a equipa de coordenação), entrega de relatórios, etc., que estão distribuídos de forma mais ou menos equilibrada ao longo do semestre.

A avaliação final do aluno engloba duas componentes: uma relacionada com a nota final no projeto, baseada no produto final do projeto, com um peso de 40%; e outra relacionada com a nota de avaliação contínua obtida na unidade curricular, com um peso de 60% na classificação final do aluno. Relativamente à nota do projeto, esta engloba uma componente individual e outra de grupo. A nota de grupo no projeto resulta da avaliação de um conjunto de elementos que constituem o produto final, nomeadamente um relatório (60%), apresentações (20%) e protótipos (20%). A nota individual de projeto de cada aluno é obtida a partir da nota de grupo no projeto. Esta nota individual obtém-se pela aplicação de fatores de correção individuais (FC) dentro do grupo, cuja média será igual a 1.0 de tal forma que a média das notas dos alunos dentro de um grupo seja igual à nota do grupo. O Fator de correção individual (FC) da nota de grupo é obtido através dos vários processos de autoavaliação e de avaliação pelos pares realizados ao longo do semestre. Os processos de avaliação pelos pares (heteroavaliação), serão efetuados com base em "avaliações por parâmetros" previamente discutidos com os alunos.

4 Metodologia

No âmbito de um trabalho de investigação realizado por Fernandes (2011), que procurou avaliar a abordagem de projeto implementada no curso de Engenharia já aqui mencionado, foi utilizado o modelo de avaliação CIPP (*Context, Input, Process, Product*) de Stufflebeam (2003) como quadro de referência para a avaliação do projeto nas suas várias dimensões (Fernandes, Flores & Lima, 2009). Os motivos que justificaram a adequação deste modelo para a avaliação da metodologia de PBL devem-se ao seu carácter "global" e sistémico, associando a avaliação à tomada de decisão. Permitiu, assim, a tomada de decisões ao longo do processo, tendo em consideração a complexidade de informações. Destaca-se, ainda, a lógica iterativa deste modelo, que pressupõe uma interação reversível entre os diferentes tipos de avaliação e decisão.

De forma resumida, a *avaliação do contexto* procurou analisar a génese do PBL no MIEGI, nomeadamente através de uma análise do panorama atual do Ensino de Engenharia em Portugal e do perfil profissional requerido pelos empregadores no sentido de identificar as necessidades e prioridades no âmbito da formação dos alunos nesta área. Tratou-se, essencialmente, de definir metas e objetivos a atingir com a implementação do PBL no MIEGI.

A *avaliação dos inputs* da formação incluiu uma análise da planificação das atividades do projeto e as respetivas estratégias de ação. Visou avaliar o momento da conceção e *design* do projeto, nomeadamente a tomada de decisões relativamente à definição do tema e objetivos esperados com a realização do projeto, a identificação das UC´s do semestre que participam no projeto, a seleção dos tutores dos grupos, a definição dos critérios para a formação de cada grupo, a (re)definição do sistema de avaliação dos alunos, a identificação e calendarização dos momentos de monitorização do projeto e respetivos resultados esperados e, por último, a identificação dos recursos disponíveis (humanos, físicos e materiais).

A *avaliação do processo* formativo centrou-se na monitorização e acompanhamento do desenvolvimento do projeto, com a preocupação de recolher informação útil e oportuna para a melhoria e funcionamento da metodologia. Pretendia-se obter *feedback* dos participantes durante o processo, permitindo reajustamentos face ao plano inicialmente definido de modo a adequá-lo às necessidades dos sujeitos envolvidos no projeto.

Por último, a *avaliação do produto* centrou-se na avaliação dos resultados e processos de aprendizagem dos alunos, partindo de uma análise das perceções dos alunos, docentes e tutores que participaram nestas experiências.

Para efetuar a recolha de dados, foram utilizados um conjunto de métodos de investigação, os quais se encontram devidamente sintetizados na tabela 1, onde são apresentados os seus objetivos e cada um dos intervenientes no processo, tendo em conta as diferentes fases da avaliação do modelo CIPP proposto por Stufflebeam (1993).

Tabela 1: Métodos, Objetivos e Intervenientes na Recolha de Dados

MÉTODOS	OBJETIVOS	C	I	P	P	INTERVENIENTES
Análise Documental	• Analisar documentos formais produzidos no âmbito do PBL (Guias de Aprendizagem do Projeto, Guia dos Tutores, Relatórios de Avaliação da experiência PBL, Publicações no âmbito do PBL, etc.).	X	X			
	• Analisar os registos escritos produzidos pelos alunos no âmbito do projeto (Relatórios Finais do Projeto, Respostas ao Teste Escrito sobre Projeto, Reflexões de Grupo, etc.).	X	X		X	
Inquérito por Questionário (Individual ou em Grupo)	• Avaliar as expetativas dos alunos face ao PBL, na primeira semana após início do projeto.		X			Alunos
	• Monitorizar e avaliar o desempenho individual dos alunos face ao trabalho em equipa, durante o projeto.			X		
	• Avaliar a satisfação dos alunos face à experiência PBL, imediatamente após a sua conclusão.			X	X	
	• Compreender as perceções dos alunos em relação ao PBL, no ano subsequente (2º ano de MIEGI).				X	
Entrevista Semi-directiva (Individual ou em Grupo)	• Conhecer o balanço dos docentes sobre a experiência PBL, após a sua conclusão.				X	Equipa de Coordenação
	• Identificar e caraterizar as práticas de tutoria no âmbito do PBL.			X	X	Tutores
	• Compreender as perspetivas dos professores, envolvidos na lecionação das unidades curriculares do MIEGI, sobre os efeitos da metodologia PBL nos processos e resultados de aprendizagem dos alunos.			X	X	Docentes do MIEGI
Focus Groups	• Avaliar o impacto do PBL na aprendizagem dos alunos, através do confronto de perspetivas entre alunos.				X	Alunos
Observação Direta	• Observar as dinâmicas de funcionamento dos grupos de alunos nas salas de projeto.			X		Alunos
	• Acompanhar o progresso dos alunos em cada *Milestone* do Projeto (Apresentações e Tutoriais).			X		
	• Analisar as perceções dos docentes e tutores nas reuniões da Equipa de Coordenação do PBL.		X	X		Docentes e Tutores
	• Participar em encontros de discussão e reflexão sobre o PBL(*Workshops*/Seminários).	X	X	X	X	
Conversas Informais	• Estabelecer um diálogo informal com os diversos participantes no PBL, facilitando o acesso à informação pretendida.	X	X	X	X	Alunos Docentes Tutores

5 Análise dos Resultados

De seguida, apresenta-se uma análise dos principais resultados obtidos na avaliação de cada uma das dimensões do modelo de avaliação CIPP. Trata-se de uma análise sintética, sendo que os resultados completos do estudo desenvolvido poderão ser consultados em Fernandes (2011).

5.1 Resultados da Avaliação do Contexto

A avaliação do contexto procurou analisar a génese do PBL no MIEGI e os motivos do seu surgimento. A este respeito, Lima, Carvalho, Flores & van-Hattum (2005) referem que a implementação da aprendizagem baseada em projetos no curso de Engenharia e Gestão Industrial teve como principal finalidade:

> «Aumentar a motivação, autonomia, iniciativa e criatividade dos alunos, passando-os progressivamente para o centro do processo de aprendizagem. Além disso, pretende-se que os seus licenciados desenvolvam

> competências para aplicação, em ambiente profissional, de capacidades de trabalho em equipa, de comunicação interpessoal e de aprendizagem ao longo da vida. (Lima et al., 2005:1788)

Os objetivos presentes no Guia do Aluno revelam também a intenção do PBL no sentido de dar resposta aos desafios inerentes à mudança de paradigma educacional proposto pela implementação do Processo de Bolonha na Universidade do Minho. A preocupação com a motivação dos alunos, a centralidade da aprendizagem do aluno e o desenvolvimento de competências surgem como características essenciais a promover no âmbito do processo de ensino e aprendizagem. Neste sentido, o PBL revelou-se numa metodologia adequada para alcançar estes objetivos.

Também foi possível constatar, sobretudo através da leitura do Relatório de Atividades do Departamento de Produção de Sistemas, referente aos anos de 2005 e 2006, que este departamento aposta fortemente na sua «afirmação como departamento de referência na implementação de novos modelos de ensino-aprendizagem», investindo na «melhoria das condições de trabalho e apoio pedagógico aos alunos de MIEGI». Em 2007, o Relatório de Atividades do DPS volta a reiterar a importância da aposta pedagógica e da afirmação do departamento «como um departamento de vanguarda» no que se refere à implementação de metodologias de ensino e de aprendizagem.

5.2 Resultados da Avaliação das Entradas

A segunda dimensão do modelo CIPP sugere a necessidade de se efetuar uma avaliação das entradas. Segundo Stufflebeam (2003), a avaliação dos *inputs* visa identificar «as coisas que são necessárias para manter ou produzir um estado de coisas desejado». Esta dimensão engloba a análise da adequação das estratégias previstas aos objetivos do projeto, com base na qual são tomadas decisões de estruturação.

Trata-se de avaliar o momento da conceção e *design* do projeto, nomeadamente os processos de tomada de decisões relativamente à definição do tema e objetivos esperados com a realização do projeto, a identificação das UCs do semestre que participam no projeto, a definição dos critérios para a formação dos grupos de alunos, a identificação e calendarização dos momentos de monitorização do projeto e respetivos resultados esperados, a identificação dos recursos disponíveis (didáticos, materiais, físicos e humanos) e, por último, a (re)definição do modelo de avaliação do projeto.

Os dados recolhidos a partir da observação e da participação direta nas reuniões de coordenação, permitiram dar conta de diferentes atitudes e níveis de envolvimento por parte dos diversos docentes responsáveis pelas UCs. Este constituiu um aspeto que se procurou explorar de forma mais aprofundada através das entrevistas individuais aos docentes, visto que as conceções e práticas dos docentes universitários influenciam significativamente o sucesso/insucesso dos alunos (Veira *et al.*, 2002, 2004).

Outro aspeto importante na fase inicial do projeto é a (re)definição do modelo de avaliação dos alunos no projeto. Considerando que já existe uma certa experiência de trabalho com esta abordagem de PBL no 1º ano do MIEGI (ver Lima *et al*., 2005, 2007; Fernandes, Flores & Lima, 2012), a avaliação tem como ponto de partida o referencial já existente dos anos anteriores, acrescentando-lhe alguns novos elementos no sentido de ajustar o processo de avaliação às características do contexto (alunos, docentes, unidades curriculares envolvidas, tema do projeto, etc.), numa tentativa de superar os principais problemas identificados durante a implementação das edições anteriores. O conhecimento destas dificuldades é facilitado pela utilização, no final de cada edição de PBL, de alguns instrumentos de avaliação, quer para os alunos (questionário de avaliação final dos alunos), quer para a equipa de coordenação (entrevista coletiva à equipa de coordenação), criados com o objetivo de identificar, compreender e melhorar os principais problemas sentidos pelos alunos e equipa de coordenação durante a realização do projeto.

5.3 Resultados da Avaliação do Processo

Os dados resultantes da monitorização e avaliação do processo permitiram dar conta das potencialidades do trabalho de projeto na promoção do desenvolvimento de um conjunto alargado de competências. A necessidade de cumprir prazos e de trabalhar em grupo permitiu aos alunos desenvolver competências de gestão de tempo, de relacionamento interpessoal, de sentido de responsabilidade, de capacidade de adaptação e flexibilidade, etc., as quais consideram fundamentais para uma futura integração profissional bem sucedida. Os alunos veem o PBL como um bom exemplo do que os espera no mundo profissional, que requer candidatos com um perfil profissional cada vez mais diversificado, onde a flexibilidade, o trabalho em equipa, o espírito crítico, a capacidade criativa e a assunção do risco assumem cada vez mais importância no perfil de procura dos Engenheiros (Fernandes, 2014).

No que se refere às perceções dos alunos, os resultados do estudo permitiram concluir que os alunos consideram que o processo de aprendizagem é mais interessante, dinâmico e estimulante com a metodologia PBL (Fernandes, Mesquita, Flores & Lima, 2014), visto que o trabalho é desenvolvido em grupo, o que favorece a partilha de ideias, a divisão de tarefas, a entreajuda, o envolvimento, etc., o que corrobora a literatura existente neste domínio (Collier, 1983; Johnson & Johnson, 1990; Topping, 1996). O trabalho em equipa constitui o aspeto mais positivo destacado pelos alunos no âmbito do PBL, a par da maior motivação face à aprendizagem devido à forte componente prática do projeto e ao seu carácter real e profissional, que culmina na apresentação de um produto. A relação que se estabelece entre professor e aluno, no contexto do PBL, foi também sublinhada pelos alunos como um aspeto positivo que contribui para melhorar o processo de aprendizagem, nomeadamente no que se refere a uma maior proximidade e *feedback*. Quanto aos aspetos menos positivos, os estudantes salientam a grande exigência quer em termos de tempo, quer em questões de sobrecarga de trabalho. Os principais desafios relacionam-se com as dificuldades na gestão do tempo e no cumprimento de prazos e com a gestão do trabalho em equipa, nomeadamente, a divisão de tarefas e o relacionamento interpessoal (Fernandes, Flores & Lima, 2007).

Relativamente às perceções dos docentes e tutores, estes destacam como principais potencialidades do PBL o impacto positivo ao nível da motivação dos alunos, o que é considerado determinante para o sucesso na aprendizagem. A relação de proximidade entre professor e aluno e entre tutor e grupo é também realçada pelos docentes e tutores que participaram no PLE, sublinhando o impacto positivo dessa relação na sua satisfação e reconhecimento profissional. Além destes aspetos, o trabalho colaborativo entre docentes surge também como uma das vantagens da participação dos docentes no PBL (Fernandes, Flores & Lima, 2009), o que constitui uma dimensão fundamental para a concretização dos princípios e pressupostos subjacentes ao processo de Bolonha.

5.4 Resultados da Avaliação do Produto

Relativamente ao impacto do PBL nos processos e resultados de aprendizagem dos alunos, verificou-se que a natureza complexa e dinâmica do projeto permitiu, a par de uma melhor compreensão dos conteúdos abordados nas diversas UCs, conseguidos graças à dimensão prática e contextualizada do projeto, desenvolver nos alunos um conjunto de competências que se revelaram cruciais para o sucesso do trabalho em equipa e do projeto realizado, nomeadamente, trabalho em equipa, resolução de problemas, gestão do tempo, capacidade de relacionamento interpessoal, capacidade de comunicação, oral e escrita, entre outras competências (Prince, 1993).

Para além do reconhecimento do contributo do projeto para o desenvolvimento das competências transversais dos alunos, foi também referido um outro aspeto quer por alunos, quer por docentes. O PBL, visto estar inserido no 1º semestre do 1º ano, tem um papel fundamental na integração dos alunos no contexto universitário, uma vez que o trabalho em equipa fomenta um maior relacionamento entre os alunos e, também, a própria abordagem de projeto obriga a um trabalho contínuo dos alunos, que é acompanhado pelos tutores e docentes de uma forma bastante regular. Este é também um dos motivos da implementação de metodologias ativas no contexto do Ensino Superior, dadas as suas potencialidades no sentido de evitar o abandono e insucesso académico dos alunos do primeiro ano da Universidade (Albuquerque, 2008).

Outro contributo significativo do PBL, na perspetiva de docentes e de alunos, reside na articulação curricular das unidades curriculares (UC) que integram o PBL, permitindo aos estudantes uma melhor compreensão e integração dos conteúdos das UCs no projeto. A transposição dos conteúdos (abstratos) para situações reais e concretas facilita o processo de aprendizagem dos alunos. Este é, aliás, um dos aspetos que vai ao encontro dos objetivos subjacentes à aprendizagem baseada em projetos, que visa promover a interdisciplinaridade dos saberes através do projeto (Heitmann, 1996; Powell & Weenk, 2003). Neste contexto, a aprendizagem baseada em projeto constitui uma estratégia pedagógica adequada à promoção e desenvolvimento dos saberes numa lógica integrada e interdisciplinar. No caso das unidades curriculares na área das Ciências, cujo insucesso académico no 1º ano do curso constitui um aspeto recorrente, foi possível reconhecer uma melhor compreensão e aplicação das matérias por parte dos alunos, quando a disciplina está inserida no PBL (Lima, Carvalho, Flores & van Hattum-Janssen, 2007).

No que se refere ao processo de avaliação dos alunos no âmbito do PBL, de uma forma geral, foi possível dar conta das potencialidades, mas também das fragilidades ou dos desafios que se colocam numa avaliação de natureza essencialmente formativa (Allal, Cardinet & Perrenoud, 1986), com preocupação pela monitorização dos processos e pela avaliação das competências disciplinares e transdisciplinares. A análise dos dados sugere que a opinião dos alunos é, de um modo geral, bastante divergente, sendo a avaliação considerada um processo justo, para alguns, e injusto, para outros (Fernandes, Flores & Lima, 2012). Os primeiros salientam as vantagens de uma avaliação que engloba vários parâmetros e que obriga a um estudo contínuo, o que traz benefícios em termos de acompanhamento da matéria das UC. Reconhecem, assim, que é mais fácil ficar aprovado a todas as UC no final do semestre, embora nem sempre permita obter classificações individuais muito elevadas. Por outro lado, os alunos que consideram a metodologia de avaliação do PLE injusta apontam, por sua vez, argumentos associados à ponderação da avaliação individual e coletiva que cada uma das abordagens pressupõe. O facto de, no PBL, a nota individual do aluno depender de outros elementos do grupo constitui uma preocupação para um número significativo de alunos. Além disso, o nível de dedicação e empenho que são requeridos ao aluno no PBL é claramente superior ao exigido no não PBL, na perspetiva dos alunos, o que gera um sentimento de "injustiça" pelo facto de a avaliação sumativa não refletir, da forma como os alunos gostariam, esse empenho individual.

As implicações do PBL ao nível do trabalho dos docentes constitui outro aspeto a considerar na avaliação do impacto deste dispositivo pedagógico. Neste sentido, da análise dos dados emergiram sobretudo três dimensões como mais significativas, nomeadamente, o trabalho colaborativo docente, a reflexão sobre as funções do docente universitário e a necessidade do desenvolver um referencial para as competências do tutor. Diversos desafios são colocados ao trabalho docente quando inserido num contexto de PBL, considerando o investimento de tempo e de esforço que os docentes dedicam ao projeto, a falta de reconhecimento e valorização institucional no que se refere à componente pedagógica do seu trabalho tem surgido como um dos principais constrangimentos. Estes constrangimentos atrás mencionados merecem reflexão no sentido de potenciar estes espaços conjuntos de reflexão e de trabalho colaborativo se se pretende melhorar processos e práticas pedagógicos e formativos no contexto do ensino superior.

6 Considerações Finais

Em jeito de conclusão, podemos dizer que a avaliação do PBL tem sido globalmente positiva, quer para alunos, quer para docentes e tutores envolvidos. A interdisciplinaridade da abordagem dos conteúdos e o desenvolvimento de projetos pedagógicos numa lógica colaborativa são fundamentais, sendo de destacar o trabalho em equipa por parte dos docentes e intervenientes neste projeto. O trabalho colaborativo inter-pares surge, de facto, como uma das mais-valias, a par da maior participação dos alunos ao longo do processo, com repercussões ao nível do seu sucesso académico e menor taxa de abandono, embora existam aspetos ainda a melhorar como é o caso da componente formativa da avaliação.

As conclusões deste estudo levantam ainda algumas recomendações para trabalhos de investigação futura. Por um lado, seria importante conhecer o impacto das mudanças pedagógicas que se têm operado ao nível do Ensino Superior, nomeadamente através da implementação de metodologias de ensino e aprendizagem ativas, como foi o caso do PBL, em termos de implicações na integração dos alunos no futuro contexto profissional. A auscultação da perspetiva dos empregadores sobre a formação inicial dos alunos "pós-bolonha" que integram o mercado de trabalho representaria um contributo importante para compreender não só as suas perceções sobre a formação inicial e as competências (técnicas e transversais) por eles evidenciadas, como também fornecer um contributo importante para eventuais reajustamentos e alterações nos planos de formação e para a definição de um perfil profissional mais claro, consistente e articulado com as necessidades reais e atuais dos contextos profissionais.

Por outro lado, este estudo demonstrou ainda a importância da formação pedagógica dos docentes universitários e da inovação pedagógica como fatores importantes para o sucesso académico dos alunos e para uma pedagogia universitária de qualidade (Tavares, 2003; Vieira *et al*., 2002, 2004). Contudo, um dos principais constrangimentos revelados pelos docentes ao nível da componente pedagógica do seu trabalho relaciona-se com a atribuição de pesos diferentes às duas principais funções do professor do ensino superior (investigar e ensinar), o que implica que o prestígio profissional dos docentes decorra, quase exclusivamente, da sua atividade de investigação e de produção científica e que a dedicação à investigação determine o acesso à estabilidade profissional, muitas vezes em detrimento da atividade docente (Dill, 2003; Escorza, 2003). Face a este cenário, é fundamental criar e assegurar condições adequadas para o desenvolvimento profissional dos professores e para o reconhecimento e valorização do seu desempenho pedagógico. Assim, consideramos pertinente o desenvolvimento de modelos e práticas de avaliação do desempenho dos docentes que promovam a valorização e reconhecimento do seu trabalho pedagógico, numa perspetiva de estímulo ao seu desenvolvimento profissional (Day, 1992).

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Interdisciplinary Project-Based Learning in the Professional Development of Science and Mathematics' Teachers

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Abstract

Interdisciplinary Project-Based Learning in is a pedagogical strategy in which projects based on real problems can be developed by groups of students, actively involved, under the coordination of the instructor, acting as mediator and coordinator of the necessary discussions and studies to obtaining results. The advantage of this approach is that students learn to interact with each other and the community around them, develop skills, acquire knowledge, develop attitudes and behaviors that allow them to cope better in a working scenario after completion of their studies. In Rio Grande do Sul, Brasil, the Polytechnic High School, being carried out in public schools, is based on the articulation of areas of knowledge and their technologies with the axes: culture, science, technology and work as an educational principle, which requires an interdisciplinary training, taking as its starting point the social context. In this scenario, the Graduate Program in Science and Mathematics Education at the University of Caxias do Sul, whose students mostly are elementary and high school teachers of public schools, held a workshop on the strategy described in this paper. For one week the participants (N = 27) were organized in interdisciplinary groups and created a project proposal that can be applied in a real context. Throughout the process data were being collected in order to analyze the PBL as a learning methodology to be implemented in primary and secondary level and its impact on teaching practice. Observations of the groups were also made considering factors such as planning, leadership, time management, communication and conflict management in the team. At the end of the course was conducted a questionnaire survey to the participants, with open questions in order to get feedback on aspects related to training (e.g. expectations), the proposals made by each group (e.g. feasibility of implementation of project proposals) while still giving space for suggestions from the participants that aimed to improve the training. Data analysis is ongoing, but preliminary results emphasize the importance of PBL in Rio Grande do Sul schools and hence the need to prepare more teachers for this methodology.

Keywords: Teachers Professional Development; Project-Based Learning; Interdisciplinarity

Aprendizagem Baseada em Projetos Interdisciplinares na Formação de Professores de Ciências e Matemática

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Abstract

A aprendizagem baseada em projetos interdisciplinares é uma estratégia pedagógica na qual projetos baseados em problemas reais podem ser desenvolvidos por grupos de estudantes, ativamente envolvidos, com a coordenação do professor, na qualidade de mediador e articulador das discussões e estudos necessários para a obtenção dos resultados. A vantagem dessa abordagem é que os estudantes aprendem a interagir uns com os outros e com a comunidade em torno deles, desenvolvem habilidades, adquirem conhecimento, desenvolvem atitudes e comportamentos que lhes permitem lidar melhor em um cenário de trabalho após a conclusão de seus estudos. No Rio Grande do Sul, o Ensino Médio Politécnico, vigente nas escolas públicas, tem por base a articulação das áreas de conhecimento e suas tecnologias com os eixos: cultura, ciência, tecnologia e trabalho enquanto princípio educativo, o que demanda uma formação interdisciplinar, tendo como ponto de partida o contexto social. Nesse cenário, o Programa de Pós Graduação em Ensino de Ciências e Matemática da Universidade de Caxias do Sul, cujos estudantes, em sua maioria, são professores de ensino fundamental e médio das redes municipal e estadual, promoveu um curso sobre a referida estratégia, descrita neste trabalho. Durante uma semana os participantes (N=27) organizaram-se em grupos interdisciplinares e criaram uma proposta de projeto passível de ser aplicada em um contexto real. Ao longo do processo foram sendo recolhidos dados, no sentido de analisar o PBL como metodologia de aprendizagem a ser implementada no nível fundamental e médio, bem como o seu impacto na prática docente. Também foram feitas observações dos grupos considerando fatores como planejamento, liderança, gestão do tempo, comunicação e gestão de conflitos na equipe. Ao final do curso foi realizado um inquérito por questionário aos participantes, com questões abertas, no sentido de obter feedback acerca de aspectos relacionados com a formação (e.g. expectativas), das propostas realizadas por cada grupo (e.g. viabilidade de implementação das propostas de projeto) e dando ainda espaço para sugestões dos participantes que visassem à melhoria da formação. A análise dos dados encontra-se em curso, mas os resultados preliminares enfatizam a relevância do PBL nas escolas do Rio Grande do Sul e, consequentemente, a necessidade de preparar mais professores para esta metodologia.

Palavras-Chave: Desenvolvimento Profissional Docente; Aprendizagem Baseada em Projetos (PBL); Interdisciplinaridade

1 Introdução

Os contextos educacionais, atualmente, caracterizam-se pela sua diversidade e complexidade, levando os docentes a novos desafios que se traduzem, principalmente, na necessidade de inovar os processos de ensino e aprendizagem. É mandatório relacionar temas das áreas tecnológicas com aspectos sociais, econômicos, tecnológicos e ambientais visando destacar a importância dessas áreas e despertar nos jovens o interesse pelo conhecimento científico e tecnológico. Propiciar inovações no aprender e no ensinar não é apenas uma necessidade, é uma imposição do momento histórico educacional. É necessário agir de modo a melhorar as práticas curriculares e pedagógicas por meio da formação continuada de professores, e promover, como consequência, melhorias na qualidade das aprendizagens. (Bell & Gilbert, 1996; Gatti, 2003; Tenreiro-Vieira & Vieira, 2005)

No estado do Rio Grande do Sul (RS), Brasil, desde 2012, foi criado o Ensino Médio Politécnico. Esta proposta de ensino demanda uma alteração nas concepções tradicionais[2] de ensino e aprendizagem (Rio Grande do Sul, 2011). A nova proposta curricular para ensino médio do RS pretende ir além da mera continuidade do ensino fundamental ou concluir a etapa final da educação básica. A iniciativa é de um ensino médio que contemple a qualificação, a articulação com o mundo do trabalho e práticas produtivas, com responsabilidade e pensamento crítico para a vida no contexto social. A proposta se constitui por um ensino médio que tem por base a sua concepção na dimensão da politecnia, constituindo-se na articulação das áreas de conhecimento e suas tecnologias: cultura, ciência, tecnologia e trabalho enquanto princípio educativo. A execução desta proposta requer uma formação interdisciplinar tanto do professor quanto do estudante, tendo como ponto de partida o contexto social, passando pelos conteúdos formais na perspectiva da solidariedade e da valorização da dignidade humana. A proposta é de uma aprendizagem significativa para o estudante e de igualdade de condições para todos, diminuindo os índices de reprovação e evasão escolar.

Esta nova proposta curricular (Rio Grande do Sul, 2011), coloca como a interdisciplinaridade deve se apresentar nos processos de ensino e de aprendizagem:

> A interdisciplinaridade se apresenta como um meio, eficaz e eficiente, de articulação do estudo da realidade e produção de conhecimento com vistas à transformação. Traduz-se na possibilidade real de solução de problemas, posto que carrega de significado o conhecimento que irá possibilitar a intervenção para a mudança de uma realidade. O trabalho interdisciplinar, como estratégia metodológica, viabiliza o estudo de temáticas transversalizadas, o qual alia a teoria e prática, tendo sua concretude por meio de ações pedagógicas integradoras. Tem como objetivo, numa visão dialética, integrar as áreas de conhecimento e o mundo do trabalho (RIO GRANDE DO SUL, 2011, p. 19).

A proposta do Ensino Médio Politécnico do RS se antecipou ao Pacto Nacional pelo Fortalecimento do Ensino Médio, proposto pelo Ministério da Educação (BRASIL, 2013). O Pacto Nacional representa a articulação e a coordenação de ações e estratégias entre a União e os governos estaduais e distrital na formulação e implantação de políticas para elevar o padrão de qualidade do ensino médio brasileiro, em suas diferentes modalidades, orientado pela perspectiva de inclusão de todos que a ele têm direito. Por meio dele, o Ministério da Educação e as secretarias estaduais de educação assumem o compromisso pela valorização da formação continuada dos professores e coordenadores pedagógicos que atuam no ensino médio público, nas áreas rurais e urbanas, e pelo redesenho curricular, em desenvolvimento nas escolas por meio do Programa Ensino Médio Inovador.

Assim, para que seja possível repensar o processo de ensino e aprendizagem, em uma perspectiva interdisciplinar e contextualizada, o professor deve compreender que ele é o mediador deste processo, no qual o estudante pode construir seu próprio conhecimento de forma ativa e significativa. Nesse ato de repensar o processo o professor precisa estar consciente de que o seu aperfeiçoamento deve ser constante para facilitar essa mediação. O aperfeiçoamento é de fundamental importância também para que o professor identifique a melhor forma de avaliar o conhecimento, que o próprio estudante construiu em sala de aula.

É nesse contexto que este trabalho se insere, ao descrever uma experiência de formação de professores com enfoque na aprendizagem baseada em projetos interdisciplinares (*Project-Based Learning* - PBL). Esta iniciativa foi realizada no âmbito do Mestrado Profissional de Ensino de Ciências e Matemática (PPGECiMa)[3], da Universidade de Caxias do Sul, da qual participaram professores do Ensino Fundamental e Médio de várias áreas de conhecimento (Matemática, Física, Química, Biologia, Português e Informática) e que atuam na rede municipal, estadual e privada do Rio Grande do Sul. Neste sentido, o presente trabalho descreve e discute os resultados deste curso de qualificação de docentes, cujo objetivo assentou-se no desenvolvimento de

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[2] Entende-se neste texto, por concepções tradicionais de ensino e aprendizagem, aquelas concepções ligadas a um ensino predominantemente conteudista, livresco e fragmentado.

[3] http://www.ucs.br/site/pos-graduacao/formacao-stricto-sensu/ensino-de-ciencias-e-matematica/

competências ao nível da aprendizagem baseada em projetos interdisciplinares, como por exemplo, trabalhar de forma colaborativa e multidisciplinar. Pretende-se com o relato desta experiência contribuir para repensar o planejamento e desenvolvimento de estratégias e contextos de formação de professores ao nível da inovação pedagógica e curricular, na qual se insere a aprendizagem baseada em projetos (PBL), bem como contribuir para a discussão sobre o papel do professor em contextos de aprendizagem interdisciplinares, como é o caso do trabalho por projeto.

2 Desenvolvimento Profissional Docente no Contexto da Aprendizagem Baseada em Projetos Interdisciplinares (PBL)

A manutenção de um modelo secular de escola reflete a estrutura dos cursos de ensino (no Brasil, licenciaturas), onde há uma tendência para a divisão do conhecimento em áreas estanques, com maior ênfase no conteúdo em si. O resultado disso é a formação de professores despreparados para estabelecer relações dos conteúdos com o cotidiano dos estudantes, o que sugere que a formação inicial de professores não contempla contextos e situações associadas às exigências que a prática profissional acarreta (Flores, 2003). No Brasil, as referências curriculares (Brasil, 1998; Brasil, 2002) se contrapõem a uma abordagem tradicional dos conteúdos conceituais de modo fragmentado, embora as práticas educativas ainda se restrinjam à transmissão e recepção de conhecimento, de forma isolada, por meio de uma organização curricular baseada em disciplinas.

Uma alternativa a este quadro é a formação continuada dos professores, por meio de cursos que propiciem o desenvolvimento de competências associadas à implementação de metodologias de ensino inovadoras, com base na proposição de atividades que possam ser transpostas ao ambiente escolar e organizadas a partir de temas abrangentes. A este respeito Auth & Angotti (2005) sugerem que a formação continuada de professores deveria incluir a proposição de temas interdisciplinares sobre ambiente ou comportamento indivíduo/grupo diante das aplicações tecnológicas, os quais possibilitam interfaces pautadas pelas diferenças e semelhanças entre a Física, a Química e a Biologia. Uma opção viável para capacitar os professores da Educação Básica a mudarem as suas práticas pedagógicas é o desenvolvimento de competências em metodologias ativas, cuja concepção de ensino é centrada na aprendizagem do estudante (Prince, 2004). Articulando com o contexto brasileiro, a Lei de Diretrizes e Bases (LDB) da Educação Brasileira, destaca que egressos de cursos de graduação das áreas das Ciências Básicas devem estar aptos a conceber, projetar, analisar, planejar, supervisionar, desenvolver práticas inovadoras, lidar com mudanças, tomar decisões adequadas, questionar e interpretar resultados, além de saber atuar em equipes e de comunicar-se fluentemente nas diversas linguagens de seu campo de atuação (Brasil. 1996). Neste sentido, ambientes de aprendizagem, que podem favorecer o desenvolvimento dessas competências, podem ser planejados por meio de espaços onde professores e estudantes interagem durante o processo de ensino/aprendizagem de forma a atingir os resultados de aprendizagem esperados, com vista a que estas experiências e situações educativas diferenciadas, que articulem a teoria e prática, contribuam para o desenvolvimento de um perfil profissional criativo e inovador, que aplica conhecimentos básicos e específicos para lidar de forma adequada com a realidade social, científica e ambiental. A aprendizagem baseada em projetos interdisciplinares (PBL) é considerada uma metodologia que se assenta nestes princípios, na medida em que prevê a realização de um projeto, por uma equipe de estudantes, a partir de um problema real articulado com os contextos profissionais, que culmina com a apresentação de uma solução/produto (Powell & Weenk, 2003). Ao propor o desenvolvimento de um projeto aberto os professores criam oportunidades para que os estudantes sejam mais responsáveis e participativos no processo de ensino e aprendizagem (Lima, Carvalho, Flores & van Hattum-Janssen, 2007). Contudo, esta metodologia levanta alguns desafios à pratica docente, por exemplo ao nível da avaliação (Fernandes et al., 2009). Por esta razão, importa preparar os professores para estes desafios, quer ao nível da formação inicial, quer ao nível da formação continuada.

3 Contexto do Estudo

Os professores do ensino fundamental e médio que participaram do curso pertencem ao corpo discente do curso de mestrado profissional oferecido pelo Programa de Pós-Graduação em Ensino de Ciências e

Matemática da Universidade de Caxias do Sul. O curso foi criado em abril de 2013 e resultou de uma longa experiência em ensino e pesquisa gerada nos cursos de Licenciatura em Matemática e Física, em Química e em Biologia. O curso de pós-graduação em ensino tem como objeto a mediação do conhecimento em espaços formais e não formais de ensino e, como principal objetivo, a construção de conhecimento científico sobre esse processo e sobre fatores de caráter micro e macro estrutural que nele interferem. A área de ensino é, portanto, uma área de pesquisa essencialmente translacional, que busca construir pontes entre conhecimentos acadêmicos gerados em educação e ensino para a sua aplicação em produtos e processos educativos na sociedade. A partir de um aprofundamento de questões teóricas e metodológicas ligadas aos processos de ensino e de aprendizagem, o Mestrado Profissional em Ensino de Ciências e Matemática atua na formação de professores em Ciências e Matemática contribuindo para a qualificação profissional de professores que atuam na educação básica, na educação técnica e na educação superior, nas áreas de Ciências, Física, Química, Matemática, Biologia e afins, em espaços formais e não formais de educação, com uma formação interdisciplinar e crítica. Nesse sentido, os projetos desenvolvidos pelos mestrandos no curso estão em sintonia com as preocupações atuais na formação cidadã dos estudantes, e vinculados ao seu ambiente profissional no qual desenvolvem suas atividades: escolas, universidades, museus, centros de Ciências, planetários, entre outros ambientes de educação. Os profissionais egressos do mestrado também estão capacitados para atuar com autonomia na pesquisa e investigação de temas relevantes para o ensino de Ciências e Matemática a fim de aprimorar continuamente sua prática didático-pedagógica ao longo da sua carreira profissional.

3.1 Descrição da Formação Docente

A formação docente desenvolvida no âmbito do Mestrado Profissional de Ensino de Ciências e Matemática (PPGECiMa) realizou-se durante uma semana, em três encontros de três horas, cujo o objetivo geral se centrou na criação de uma proposta de projeto (PBL) passível de ser implementada nos contextos profissionais dos participantes. Para tal, um conjunto de pressupostos teóricos foram abordados, tendo sido articulados com atividades práticas que culminaram com a apresentação de uma proposta de projeto por parte das equipes que foram constituídas logo na primeira sessão. Outro dos objetivos esperados consistiu precisamente no desenvolvimento de competências de comunicação e trabalho colaborativo docente, por meio de estratégias de aprendizagem ativa e de discussão entre os participantes. Assim, constituíram-se três equipes multidisciplinares de 6 a 8 elementos (N=27) e que, preferencialmente, atuassem no nível de ensino fundamental ou médio.

A criação da proposta de projeto foi sendo desenvolvida pelos grupos ao longo das sessões e acompanhada pela formadora (externa à instituição) e por seis professores associados ao mestrado, que foram observando a dinâmica entre os participantes, registrando aspectos, que merecessem destaque, relacionados com planejamento, gestão do tempo, comunicação e gestão de conflitos nas equipes. Assim, a proposta de projeto desenvolvida pelos diferentes grupos teria de contemplar o enquadramento curricular, a definição do problema, os resultados de aprendizagem e a metodologia de avaliação. Outros aspetos poderiam ser sugeridos pelos grupos, caso tivessem tempo necessário à sua discussão e desenvolvimento.

Ao colocar os professores participantes para criar uma proposta de projeto, pretende-se simular as condições reais de uma equipe de coordenação de professores, em que é possível que desenvolvam as competências que são esperadas nestes contextos, tais como: trabalhar em equipe, comunicar eficazmente, resolver conflitos, negociar e partilhar ideias e planejar os requisitos do projeto, entre outros aspectos.

3.2 Coleta e Análise de Dados

Considerando o objetivo inerente a este trabalho, que visa descrever a experiência de formação de professores sobre a aprendizagem baseada em projetos interdisciplinares (PBL), foram sendo recolhidos dados e informação ao longo da formação, com vista a fazer uma avaliação da mesma, considerando a perspectiva dos participantes envolvidos.

Para além das observações realizadas pelos professores associadas ao mestrado ao longo do processo, tal como referido anteriormente, foi ainda aplicado um inquérito por questionário no final da formação, com questões abertas, formulado com o propósito de auscultar a percepção dos professores acerca de aspectos relacionados à proposta da formação (expectativas, aspectos positivos e aspectos menos positivos) e sobre o resultado alcançado por cada grupo (satisfação, ou não, com a produção da equipe, dificuldades encontradas na produção e viabilidade de implementação dos projetos nas escolas). Outra questão, no final do questionário, propiciou a cada participante apresentar sugestões que visassem à melhoria da formação. Responderam ao inquérito por questionário 16 de um total de 27 participantes.

A análise dos resultados apresentada na próxima seção deriva da intersecção dos registros efetuados pelos professores observadores ao nível da dinâmica das equipes ao longo da concretização do projeto e pelos resultados dos inquéritos por questionário realizado aos participantes na formação.

4 Apresentação e Discussão dos Resultados

Os resultados apresentados incidem sobre três aspectos fundamentais que derivam da avaliação do processo da formação de professores realizada. Em especial é descrita a dinâmica das equipes, de acordo com os registros dos professores que observaram o processo, e ainda são apresentadas as perspectivas dos participantes sobre a formação em geral, sobre o resultado alcançado e ainda indicando sugestões de melhoria para próximas edições deste curso de formação continuada.

4.1 Dinâmica das Equipes

A primeira equipe foi constituída por professores de Ciências e de Língua Portuguesa, atuantes no Ensino Fundamental de diferentes escolas municipais e estaduais do RS. A primeira discussão incidiu sobre escolha do líder, o qual foi indicado por unanimidade pelos participantes. Posteriormente, a equipe dedicou-se à primeira atividade associada ao projeto que assentou na seleção e escolha de um problema contextualizado e que estivesse inserido em um dos temas transversais do Ensino Fundamental, tendo sido escolhido o tema "Alimentação". Foi possível perceber a motivação, a colaboração e o comprometimento de todos os participantes no planejamento de ações, na troca de ideias, no cumprimento das tarefas e na gestão do tempos. A equipe teve uma atuação profissional não se denotando a existência de conflitos. Outra etapa consistiu no enquadramento curricular do problema, a qual não apresentou dificuldades em função da escolha do tema, que partiu do levantamento de conteúdos já trabalhados pelos professores. Cada professor explicitou objetivos, habilidades, atividades e formas de avaliação, incluindo a autoavaliação que foi proposta em cada conteúdo e, assim, cada professor pode ampliar o planejamento de suas disciplinas. Foi possível perceber um ambiente propício ao diálogo entre disciplinas e professores, caracterizando uma atitude interdisciplinar. Finalizaram os trabalhos com várias sugestões para a obtenção dos resultados esperados, como produto do desenvolvimento do projeto. No encontro de apresentação das propostas de projetos, foi sugerido à equipe que revisasse o cronograma do projeto, definindo os vários momentos das apresentações dos estudantes e os das avaliações.

Uma segunda equipe, formada por professores de Física, Informática, Matemática, Biologia e Português atuantes no Ensino Fundamental e Médio de diferentes escolas municipais, estaduais e particulares do RS, já iniciou a discussão sobre temas relevantes para serem abordados em projetos, levando em consideração a aprendizagem baseada em projetos. Apesar de não terem, formalmente, apontado um líder, este foi identificado na observação, como sendo quem iniciou a problematização, sugerindo, inicialmente, a água como tema motivador. Inicialmente todos participaram com argumentos favoráveis à escolha do tema. Passaram, então, à discussão sobre a metodologia, com a definição das disciplinas a serem envolvidas no projeto, bem como os resultados de aprendizagem esperados e respectivas avaliações, em cada uma das disciplinas. No decorrer da discussão, que contou com a intervenção de todos os colegas, alguns ainda indecisos quanto ao tema, o grupo tomou a decisão de refletir um pouco mais à respeito do tema. Neste primeiro encontro, finalizaram a discussão, com o acordo de, ao mesmo tempo em que aprofundariam seus estudos sobre a metodologia, refletiriam sobre um tema que considerassem mais adequado, visando à implementação nas respectivas disciplinas de atuação. De fato, a apresentação do trabalho final expôs o projeto Energia Elétrica, problematizando "o alto custo da energia elétrica, gerado pelo consumo excessivo desta energia proveniente de usinas hidrelétricas, provoca impactos ambientais, econômicos, políticos e sociais". E para o trabalho em cada uma das disciplinas selecionadas para a implementação do projeto, levantaram a seguinte questão: "Vamos imaginar que a cidade de Caxias do Sul sofra um apagão. Quais seriam as alternativas para solucionar o problema do apagão, levando em conta questões ambientais, econômicas, políticas e sociais?". Justificaram a possibilidade de envolver as disciplinas de Física, Matemática, Biologia, Geografia, História, Sociologia, Português, Robótica e Informática para o Ensino Médio. Para cada uma delas foram definidos os conteúdos e resultados de aprendizagem esperados. Ainda que de forma superficial, a avaliação foi abordada, com a previsão de levar em consideração a aprendizagem do estudante por meio dos questionamentos, diálogo, atitudes investigativas, trabalho em equipe e envolvimento, mudanças de atitudes diárias referentes à questão da energia elétrica na escola. Além disso, também foi prevista a avaliação da apresentação de trabalhos a serem propostos e auto-avaliação realizada por todos os participantes, individualmente e pelos respectivos grupos.

A terceira equipe foi formada por professores de Ensino Médio da rede pública de escolas do RS, que atuam nas áreas de Física, Química, Biologia e Matemática. No início dos trabalhos, os professores envolveram-se com a definição de um problema de pesquisa que deveria ser aberto, real, atual e interdisciplinar. Para isso, os integrantes da equipe informaram aos colegas quais eram seus respectivos campos de atuação, permitindo que partilhassem os seus interesses e perspectivas e, com isso, conheceram-se melhor para poderem trabalhar colaborativamente. Assim, concordaram com o tema que entendiam ser mais comum e escolheram o "Aproveitamento da Água da Chuva". Foi possível observar que houve ampla participação de todos e não houve a escolha de uma liderança específica. A segunda etapa consistiu no enquadramento curricular do problema, o qual não apresentou dificuldades em função do processo de escolha do tema já ter sido a partir do levantamento dos conteúdos ministrados pelos integrantes nas escolas. Assim, esta tarefa consistiu em listar o que cada professor poderia aprofundar em suas disciplinas. A maior dificuldade encontrada, e a que gerou um debate mais acalorado, deu-se na etapa de definição das produções dos estudantes e de um produto do projeto a ser aplicado na escola. Houve certa dificuldade dos integrantes da equipe em separar a proposição de atividades pelos professores e as produções dos estudantes. Em certa medida, a escolha de um tema abrangente propiciou um grande número de sugestões. Nesse processo, foi necessária a intervenção da tutoria para que houvesse uma redução das propostas, a fim de viabilizar a realização do projeto na escola em um período que não ultrapassasse o de um semestre letivo. De parte dos professores que atuaram como tutores, foi sugerido à equipe que as produções dos estudantes e o produto da pesquisa fossem definidos a partir dos critérios estabelecidos para a avaliação. Em relação à avaliação, não houve uma discussão mais aprofundada nesta equipe, e todos concordaram que seria necessário mais tempo e suporte teórico às equipes para a concretização desta tarefa, que, como todos também concordaram, é essencial.

4.2 Percepções gerais sobre a formação

Os professores responderam se as expectativas que tinham em relação à formação foram ou não alcançadas. Todos (100%) responderam que as suas expectativas foram plenamente alcançadas. Ao justificar, espontaneamente, tal afirmação, 50% destacou, especialmente, a metodologia proposta para a elaboração de um projeto e a dinâmica da formação, promovendo a participação de todos. 42% dos professores manifestou ter tido a oportunidade de conhecer, aprofundar conhecimentos ou esclarecer dúvidas sobre PBL. Outros professores referiram que PBL era um tema de interesse e que foi possível estabelecer relações significativas entre PBL e as práticas aplicadas nas aulas. Também foi manifestada a satisfação em conhecer um pouco sobre como é a educação em Portugal, e pela interação com professores do mestrado, o que despertou interesse por seguir a formação no Mestrado em Ensino de Ciências e Matemática da UCS.

Ao responderem a segunda pergunta, os professores falaram de aspectos que mais gostaram na formação realizada. A maioria das respostas, 88%, indicava a metodologia como ponto alto da formação. Dentre as respostas apresentadas, 42% destacaram as atividades planejadas para a formação; como referiram alguns, com "intervenções importantes da professora formadora, especialmente, abrindo e fechando cada etapa", com "atividades diversificadas e práticas", com "atividades para fazer pensar", com "dinâmica criativa" e com "ações proveitosas, pois em pouco tempo aprendemos muitas coisas". Outro destaque, igualmente apresentado, 42%, foi a estratégia de atuação em equipes para a elaboração das propostas de projetos, revelada em expressões como: "trabalho interdisciplinar com colegas", "espaço de debates e discussão de ideias", "realizar com colegas uma atividade de PBL", "momentos de interação" e "discussões acerca do assunto e conhecendo novos colegas". Ainda sobre o que mais gostaram na formação, quatro professores realçaram o fato de terem executado, na prática, o planejamento de um projeto; outros dois professores disseram que foi muito importante receber referências de materiais que auxiliarão em trabalhos e estudos futuros, e um professor distinguiu o fato de ter aprendido uma nova metodologia de ensino e aprendizagem.

A terceira questão proposta era, então, sobre o que os professores não gostaram na formação. Pelo que se percebeu nas respostas às duas primeiras questões, já era esperado não haver aspectos relevantes de que não gostassem. O que a maioria, 63%, respondeu foi que o tempo da formação poderia ter sido maior. Um professor lamentou não ter estado na manhã do sábado em que foram apresentados os projetos, outro que, devido ao dia de trabalho realizado na escola, "a parte da aula que era expositiva tornava-se cansativa". Apenas um professor revelou "dificuldades de interação com os colegas na realização da atividade à distância". Por fim, três professores, afirmaram não haver "nada a declarar" e um desses acrescentou: "O curso foi 100% aproveitável".

4.3 Percepções sobre os projetos elaborados

Outras três questões foram propostas, para ter a visão dos participantes sobre as produções que realizaram: se ficaram satisfeitos com o projeto proposto, que dificuldades encontraram e se reconheciam haver viabilidade para a implementação da proposta.

Sobre a satisfação por ter elaborado uma proposta de PBL, 75% dos professores afirmou que sim, justificando com argumentos que destacam a construção "feita em equipes com várias mãos e olhares", uma "real possibilidade de construir" uma estratégia interdisciplinar, a colaboração de cada área representada no grupo. Destacaram, também, a satisfação em "criar uma novidade para a escola", criar projetos que podem ser aplicados, e que, "conforme os resultados podem ser melhorados", além da satisfação por terem aprendido "bastante com esta experiência". Os demais, 25%, mostraram-se parcialmente satisfeitos, dois professores sob a alegação do pouco tempo da formação, um professor dizendo que o grupo procurava propor projetos que já conheciam "ao invés de procurar construir um que fosse novo para todos" e outro, ainda, que encontrou pouco espaço na interação com o grupo, que pouco considerava as ideias apresentadas.

Quanto às dificuldades que enfrentaram para a concretização da proposta, novamente o pouco tempo da formação foi apontado, por 38% dos participantes. "Lidar com ideias divergentes e chegar a consensos" foram as maiores dificuldades apontadas por 20% dos professores. Outro fator apontado, também por 20% dos professores, foi a dificuldade de compreender e estabelecer relações entre o tema do projeto e os conteúdos escolares. Alguns desses e alguns outros professores, totalizando 20%, manifestaram dificuldades operacionais como definir o tema, propor um problema suficientemente aberto para integrar várias áreas e compreender a sequência operacional do método científico. Por fim, 25% dos professores afirmou que não foi fácil trabalhar a distância para adiantar a operacionalização da proposta, "por dificuldades na interação", na troca de mensagens e "na gestão das participações".

Sobre a possibilidade de implementar a proposta nas suas escolas, o sim foi unânime. Todos entendem que o projeto elaborado pode ser aplicado, e alguns, no caso três professores, consideram a necessidade de "fazer ajustes e adequações à realidade da escola", "de contar com o apoio de colegas", com um "bom planejamento das ações" e com um "coordenador empenhado em comprometer os professores" das áreas envolvidas. Ao justificar porque o projeto é viável, 32% dos professores disse que o tema é relevante, "tanto no campo das Ciências do currículo escolar" quanto em relação a aspectos sociais, "integrados ao dia a dia dos estudantes". Outros 25% apontaram, como ponto forte, as atividades que foram programadas, "atividades ativas", disseram dois professores, "relevantes, simples e significativas, que despertarão o interesse e a curiosidade" dos estudantes, consideraram três professores, e outro professor identificou a possibilidade de "aplicar as mesmas atividades no Ensino Fundamental e, com devidas adaptações, também no Ensino Médio". Relevando o caráter interdisciplinar do projeto, manifestaram-se três professores, um desses afirmando que a proposta pode integrar "todas as disciplinas do Ensino Médio". E, ainda, em relação à aprendizagem, um professor salientou que "trabalhar com PBL facilitaria o interesse e a aprendizagem", promovendo os estudantes como construtores dos seus conhecimentos. Outro encontrou na metodologia de projetos uma oportunidade de "trabalhar conceitos de forma diversificada" e um terceiro professor afirmou que o "PBL permite ao estudante aprender de uma forma diferenciada".

4.4 Sugestões de melhoria

Como sugestões de melhoria, os participantes apontaram, novamente, a necessidade de mais tempo para a formação, com vista a ter mais tempo entre a formação e a concretização das propostas, ou seja, "para a elaboração, propriamente dita do projeto", disse um professor, justificando que o "planejamento deveria ser desenvolvido de forma mais consistente", comentou outro e outro, ainda, que poderia ter "até uma agenda de atividades a cumprir com exigências solicitadas para a proposta final". Outra sugestão dada, por três professores, foi a de formar grupos menores, "para que a interação seja mais dinâmica e próxima, facilitando assim o desenvolvimento da proposta, tanto em atividades presenciais, como a distância", destacou um professor. Além dessas, foram apresentadas, cada uma por um professor, sugestões como: "fazer uma avaliação diagnóstica, levantando conhecimentos prévios", "receber uma avaliação dos trabalhos", manter a abordagem de aprendizagem ativa e promover debates entre os grupos na apresentação final.

5 Considerações Finais

O professor necessita de conhecimentos e estratégias que vão além de sua formação inicial, ou seja, ele necessita de uma formação continuada, que implica na continuidade da formação profissional, proporcionando novas reflexões sobre suas ações, e novos meios para desenvolver e aprimorar o trabalho pedagógico. Esta formação continuada deve ser um processo de construção permanente do conhecimento e desenvolvimento profissional, a partir da formação inicial, para assim construir uma prática pedagógica interdisciplinar, voltada para a pesquisa, para o uso de tecnologias e novas metodologias.

Considerando as várias mudanças ocorridas nos sistemas educacionais a nível estadual e nacional no Brasil nos últimos anos, é imprescindível que oportunidades sejam criadas para que os professores se capacitem e possam assumir o papel de mediador em sala de aula.

Após seis meses da realização do curso, solicitou-se aos participantes um feedback acerca do ponto de situação da implementação das propostas nas escolas onde atuam. Neste sentido, verificou-se que as propostas realizadas no curso estão sendo analisadas a nível institucional de forma a viabilizar a implementação do projeto.

Nesse contexto, acreditamos que o curso oferecido pelo PPGECiMa aos professores de ensino fundamental e médio em aprendizagem baseada em projetos interdisciplinares apresentou a eles uma estratégia com grande potencial para alcançar, por exemplo, os objetivos da proposta de Ensino Médio Politécnico do estado do Rio Grande do Sul. Com essa estratégia, esses professores poderão envolver seus estudantes ativamente no processo de ensino aprendizagem e também poderão proporcionar a estes estudantes um ambiente em que os mesmos aprendam a interagir uns com os outros e com a comunidade em torno deles, desenvolvam habilidades, adquiram conhecimento, e desenvolvam atitudes e comportamentos que lhes permitam lidar melhor em um cenário de trabalho após a conclusão de seus estudos.

A observação realizada pelos professores do mestrado e as respostas dadas pelos participantes do curso ao inquérito por questionário apontam a relevância do PBL para o Ensino Médio Politécnico do estado do Rio Grande do Sul e, consequentemente, a necessidade de preparar mais professores para esta metodologia.

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Application of the PBL Methodology in Engineering Education: a Case Study

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Abstract

This paper presents the results of the experiment using the PBL method (Project Based Learning) at the Federal University of Pará, Tucuruí Campus, located in the Amazon region. Given that one of the pressing problems of the Amazon and the world is inadequate waste disposal causing damage to the environment and therefore to society, started an environmental education at the University through the Gadget Lab (Laboratório de Engenhocas) extension program, which consists the use of recycled materials for the preparation of physical experiments. Knowing the advantages of PBL, it applied the method in Experimental Laboratory disciplines of Civil Engineering Courses, Mechanical and Electrical Engineering, and the conducted by professors and students participate in the Gadget Lab. During the discipline was required for the class presentation of projects related to the course and that used recycled materials, serving as a criterion for evaluation. There was acceptance certain aspects: the use of low cost materials fact that helped in the execution of some experiments and also the ease of reproduction of experiments extra time which was not possible with the use of traditional laboratory equipment.

Keywords: Tutors; Active Learning; Engineering Education; Experiments.

Aplicação da Metodologia PBL para Educação em Engenharia: Um Estudo de Caso

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Resumo

Este trabalho tem por objetivo apresentar resultados de experiências utilizando o método PBL (Projecto Based Learning) na Universidade Federal do Pará, Campus Universitário de Tucuruí, localizada na região Amazônica. Atualmente, um dos grandes problemas que causa preocupações na Amazônia e no mundo é a inadequada eliminação de resíduos, podendo causar danos ao meio ambiente e, consequentemente, para a sociedade. Para isso, foi iniciada uma educação ambiental no Campus Universitário, através do programa de extensão Laboratório de Engenhocas, que consiste na utilização de materiais reciclados para a preparação de experiências físicas. Sabendo das vantagens que o PBL pode proporcionar, aplicou-se o método nas disciplinas de Laboratório Experimental, dos Cursos de Engenharia Civil, Engenharia Mecânica e Engenharia Elétrica, conduzindo a experiência através de professores e alunos do Laboratório de Engenhocas, sendo este último os tutores. Durante a disciplina solicitou-se a turma apresentação de projetos relacionados ao curso utilizando materiais reciclados, servindo como um critério de avaliação. Por imediato, houve resistência dos discentes com as atividades, posteriormente, veio a aceitação devido alguns aspectos que favoreciam a utilização da metodologia: o uso de materiais de baixo custo, fato que ajudou na execução de algumas experiências, facilidade de reprodução das experiências em tempo extra classe, que não foi possível com o uso dos equipamentos tradicionais do laboratório.

Palavras-chave: Tutor; Aprendizagem Ativa; Educação em Engenharia; Experimentos.

1 Introdução

Atualmente é bastante discutido sobre as deficiências do atual modelo de formação profissional. As principais questões fazem referência principalmente ao atual modelo educacional convencional, baseado na transmissão e recepção de conhecimentos entre o professor e o aluno. Na sala de aula convencional, os alunos são vistos como receptáculos vazios a serem preenchidos por conhecimentos validados pela teoria e distribuídos pelo professor. Na formação em engenharia, é comum encontrar a crítica de que os métodos de ensino-aprendizagem empregados não favorecem os atributos estipulados em suas diretrizes ou recomendados pelas associações profissionais, já que o modelo de transmissão-recepção de informações não lhes estimula o desenvolvimento da criatividade, do empreendedorismo e da capacidade de aprender autonomamente (Ribeiro, 2008). Com isso, é importante incentivar o uso de metodologias que aproxime o aluno ao professor, facilitando o aprendizado e consequentemente diminuindo a evasão dos cursos de engenharia.

Mesmo tendo o incentivo e participação dos docentes, é necessário partir do aluno o interesse em desenvolver as atividades em sala. Portanto, é preciso estimular que o aluno seja proativo, sendo uma das principais características requeridas para os profissionais em engenharia. Com isso, faz-se necessário o estímulo profissional desde o início de sua carreira acadêmica. Assim, com auxílio dos tutores, alunos dos cursos de engenharia, podem recorrer à utilização de distintas metodologias com o intuito de proporcionar aos estudantes uma oportunidade para o desenvolvimento desta habilidade. Uma destas metodologias é o PBL ("Project Based Learning") voltada ao aprendizado baseado em projetos. Mesmo com iniciativas de utilização de novas metodologias para o ensino em engenharia, não existe consenso quanto à inadequação da abordagem clássica à educação, em que um único professor trabalha em frente a uma grande classe de estudantes, usando um livro-texto e testes, mas também há outras abordagens para a aprendizagem que fazem uma contribuição positiva para o desenvolvimento da aprendizagem (Pouzada, 1999; Campos, 2009; Sousa 2000; Nobre, 2006).

Dessa forma, o PBL proporciona ao aluno a aquisição de conhecimento crítico, proficiência em solução de problemas, estratégias auto direcionadas de aprendizagem e habilidades de participação (Powell & Weenk, 2003; Barrows & Kelson; Weenk & Blij, 2011). Assim, pode-se definir o PBL, como a metodologia que procura desenvolver a autonomia do aluno na solução de problemas e na construção de conhecimento por meio da concepção de um projeto e do trabalho em equipe.

Entretanto, o alcance de um estado satisfatório na postura de pró-ativados discentes, depende de diversos fatores. Entre estes fatores se destacam aqueles ligados ao papel do tutor, tais como: a motivação para uma nova experiência didática e a orientação adequada nos estágios iniciais do processo. Em muitas ocasiões o papel de tutor pode ser aplicado a um grupo de estudantes vinculados a orientação constante de professores.

A utilização de estudantes como tutores foi bem sucedida em experiências realizadas, por exemplo, na Universidade de Tecnologia de Eindhoven por Puente, Jongeneelen, & Perrenet (2011)que conseguiram estimular a criatividade, aeloquência, e o senso crítico dos tutores alunos. Assim, adaptando-se o trabalho mencionado anteriormente, optou-se pela utilização de alunos de graduação como tutores nas disciplinas de laboratório de física dos cursos de Engenharia Civil, Elétrica e Mecânica do Campus Universitário de Tucuruí.

Os alunos escolhidos como tutores são estudantes dos cursos de engenharia e participantes do programa de extensão intitulado "Laboratório de Engenhocas". Os participantes deste projeto têm por característica principal a apresentação de experimentos de física utilizando materiais alternativos e de baixo custo. Para implementação da metodologia desenvolvida pelos tutores junto aos alunos, inicialmente, percebeu-se uma resistência por parte dos discentes em não aceitarem serem acompanhados por tutores, já que os mesmos também são alunos, com o desenvolvimento da atividade, os alunos perceberam a preparo e competência dos tutores, assim aceitando a implementação da metodologia.

Desta forma, neste artigo apresentam-se os resultados da aplicação da metodologia PBL como uma forma de estimular nos discentes da disciplina o pensamento crítico, trabalho em equipe, eficácia e eficiência na comunicação para a resolução de problemas e concepção de projeto. Desejava-se ainda com a aplicação da metodologia, agora em relação aos tutores, o desenvolvimento de competências de planejamento, gestão, comunicação e trabalho em equipe.

2 Metodologia

A metodologia foi aplicada em turmas de engenharia elétrica, civil e mecânica do Campus Universitário de Tucuruí na disciplina de laboratório de física. Para todos os cursos, a carga horária desta disciplina é de 60 horas ministradas em duas semanas, sendo parte dessa carga horária do curso dedicado ao PBL.

Para a metodologia utilizada dividiu-se cada turma em duas e após a divisão tendo em média 20 pessoas cada, sendo o critério de divisão aleatório, pois segundo Andersen (2011), não se pode apenas reunir um grupo de indivíduos altamente criativos, colocá-los juntos e esperar que os mesmos tenham o melhor desempenho. Realizou-se ainda a subdivisão de cada turma em grupos de cinco pessoas. As subdivisões servem para facilitar o trabalho e criar oportunidade para todos os alunos participarem das discussões, algo característico da metodologia (Pouzada, 1999).

O planejamento das atividades ocorreu com algumas semanas de antecedência em relação à disciplina disponibilizada para cada curso. Para a organização, reuniram-se o professor da disciplina e os tutores (alunos do projeto "Laboratório de Engenhocas"). Desta forma, os tutores orientados pelos professores compreendiam a dinâmica de equipe que deveria ser aplicada no planejamento do PBL. Fato que proporcionou em cada tutor um determinado papel na seleção e preparo das atividades a serem desenvolvidas com os discentes.

O cronograma estava definido de acordo com a duração da disciplina, isto é, dez dias ao longo de duas semanas letivas (*Figura 1*), com cinco horas aula por dia. Para a aplicação do PBL, destinou-se para cada turma uma semana: uma turma trabalharia com os tutores na sua primeira semana de aula e a outra, na segunda semana. Na semana em que não estavam com os tutores, os alunos executariam as atividades no Laboratório de Física, utilizando os kits convencionais (industrializados) de experimentos sob a supervisão direta do professor e do monitor do laboratório. Na semana em que se trabalhou com o PBL, as aulas ocorreram na sala da própria turma.

	Semana 1	Semana 2
Turma 1	Atividades "tradicionais" no Laboratório de Física	Aplicação do P2BL
Turma 2	Aplicação do P2BL	Atividades "tradicionais" no Laboratório de Física

Figura 1. Cronograma geral de atividades.

Conforme esquematizado na Figura 2, no início das aulas apresentava-se aos discentes, a área de estudo que seria abordada e quais experimentos seriam discutidos durante a aula. Em seguida, os tutores auxiliavam os alunos na montagem e execução do experimento, havendo ao término discussões sobre os princípios físicos observados. De acordo com os dados coletados e os tópicos discutidos, os grupos se reuniam novamente para repetir a coleta de dados, desta vez constatando aspectos não observados na primeira execução. Os dados foram registrados em relatório como critério de avaliação. Estes procedimentos se repetiam a cada experimento realizado. Paralelamente a este processo, os alunos desenvolveriam um projeto, que deveria ser apresentado no final da disciplina. Os projetos apresentados estavam de acordo com a área de afinidade cursada pelo discente, por exemplo, os discentes de Engenharia Elétrica apresentavam projetos envolvendo Eletromagnetismo aplicado.

Figura 2. Processo de trabalho, possuindo os experimentos um caráter de problema e sendo repetido a cada novo assunto enquanto o projeto era elaborado paralelamente em horários extraclasse (SILVA et al., 2012b).

O projeto solicitado aos grupos formados deveria ser realizado com materiais alternativos e de baixo custo. A apresentação deveria ser de acordo com o modelo característico do projeto Laboratório de Engenhocas, em que o experimento é apresentado de maneira lúdica e interativa para melhor explanação dos conceitos físicos envolvidos. Procurava-se, desta forma, estimular o aproveitamento, redução, reutilização de matérias descartáveis, assim como, estimular a responsabilidade socioambiental (BRASIL, 2010).

O assunto a ser abordado com a realização do projeto foi uma escolha de cada grupo. Uma vez que os alunos definiam o que seria realizado, os mesmos deveriam responder questionamentos do tipo: como desenvolver o projeto idealizado? Quais adaptações deveriam ser feitas para que se fizesse uso dos materiais de baixo custo? Que aplicações na engenharia se relacionavam com o que se desenvolveu? Qual a melhor maneira de repassar as informações pesquisadas? Uma vez definidas estas questões, os experimentos poderiam ser construídos. No entanto, além da construção, exigia-se a apresentação oral do experimento em sala de aula.

Ao término da disciplina também foi exigido dos alunos que entregassem, em forma de artigo, a aplicação dos experimentos trabalhados no projeto, além de relatórios a respeito dos dados coletados durante a abordagem de cada experimento em sala de aula.

Na metodologia utilizada, os tutores participavam na demonstração dos experimentos previstos na ementa. Estas demonstrações serviriam de modelo para os discentes da disciplina, pois os mesmos deveriam apresentar seus projetos ao final da disciplina como critério de avaliação. Adicionalmente, os tutores, no início do cronograma de atividades, deveriam orientar os alunos na definição e execução dos projetos propostos pelos discentes da disciplina, fornecendo *feedbacks* sobre a relevância dos temas escolhido cada equipe.

Na aprendizagem baseada em problemas, nunca se sabe quais serão as perguntas dos alunos, mas todas elas obrigam o professor e o tutor a estarem atualizados. O papel do tutor não é de dizer exatamente o que ele deve aprender e em que sequência deve fazê-lo, o tutor deverá ajudar os estudantes a determinarem isto de forma independente. Direciona-se, portanto, o aluno para sua autonomia na aprendizagem (Enermark & Kjaersdam, 2009; Campos, Dirani & Manrique, 2011).

A participação ativa do professor foi exigida para acompanhamento e orientação dos tutores, tanto ao sugerir contextualizações na fase de planejamento quanto ao avaliar o desempenho dos alunos tutores durante e após cada aula. A análise do desempenho dos tutores, por exemplo, incluíam-se a clareza na abordagem dos conceitos de física, a gestão do tempo, o correto acompanhamento nas coletas de dados e a eficiência das estratégias planejadas.

3 Resultados

Durante as aulas, os tutores garantiam à execução dos planos previamente definidos, assim como, a gestão adequada do tempo com intuito de propor o melhor desempenho possível quanto à comunicação entre tutores e discentes. No entanto, observou-se que o acompanhamento das atividades dos discentes da disciplina requeria maior parcela de tempo aos tutores, não sendo suficiente o tempo reservado durante parte das aulas. Para superar esta dificuldade, foi necessária a intervenção do professor, contribuindo na orientação dos projetos, sobretudo nos horários extraclasse.

Os discentes apresentaram certa resistência à aplicação do método, já que parte da disciplina seria utilizando materiais alternativos, mas no decorrer das atividades passaram a entender a importância da atividade que estava sendo desenvolvida. A utilização de materiais de baixo custo também possibilitou a reprodução dos experimentos a qualquer momento e local pelos alunos, causando impactos na sua aprendizagem por não os limitar à sala de aula, permitindo a revisão de conceitos e tornando viável a aplicação da teoria para a resolução de um problema por meio de um projeto.

De acordo com as atividades previstas, quanto às apresentações dos projetos, percebeu-se que os alunos optaram por temas de grande repercussão. Para o curso de engenharia elétrica, observou-se, por exemplo, a utilização de conceitos relacionados a geração e distribuição de energia (Figura 3 e *Figura 3*). Para o curso de mecânica, a utilização de conceitos relativos ao curso, como por exemplo, a propulsão de foguetes aliado a leis da física. Para os alunos de civil forma realizados experimentos concernentes à resistência dos materiais usando materiais alternativos, como por exemplo, o experimento "Flutuando em Balões" onde foi possível colocar em prática o conceito de pressão e estudar sobre os materiais elásticos (Figura 5). Os assuntos corroboram a importância de experiências prévias dos discentes com seus respectivos cursos.

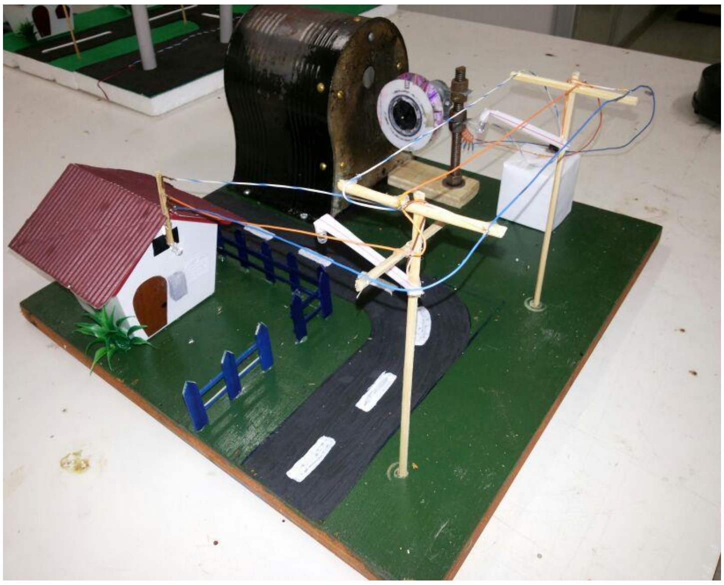

Figura 3. Protótipo de uma turbinatérmica conectada a um sistema elétrico de distribuição (representativo). Atividade realizada por grupo de discentes do curso de engenharia elétrica.

Figura 4. Protótipo de uma turbinahidráulica conectada a um sistema elétrico de distribuição (representativo). Atividade realizada por grupo de discentes do curso de engenharia elétrica.

Figura5 - Experimento "Flutuando em Balões" realizados por discentes do curso de Engenharia Civil, 2011.

Como ponto positivo, observou-se no momento de desenvolvimento dos experimentos, os alunos realizavam filmagem dos experimentos físicos. Com isso, possibilitou em alguns experimentos como o foguete de balão, o cálculo de velocidade, aceleração e também a influência do ângulo de lançamento para o alcance e altura máxima.

Terminada a disciplina, verificou-se por meio de um questionário a opinião dos discentes acerca da metodologia adotada, visando possíveis adaptações na forma de trabalho. Um total de 94 discentes das turmas de Engenharia optaram por responder ao questionário composto por três questões objetivas e uma discursiva.

Na

Figura 5 estão representadas as respostas às questões objetivas. Em análise, percebeu-se que os alunos estão atentos para as questões ambientais, tornando relevante a abordagem realizada tanto usando experimentos com materiais alternativos quanto os kits adquiridos de fabricantes (experimentos industrializados). A utilização dos Kits foi importante na opinião dos discentes, o que permitiu que houvesse mais flexibilidade na ementa da disciplina. Constatou-se também que a prática contribuiu para um novo olhar quanto à utilização destes materiais no ensino de engenharia, assim como, estimulou nos discentes a responsabilidade socioambiental. Nos gráficos abaixo estão dispostos os resultados dos seguintes questionamentos realizados com os alunos: (a) Questão 1: É válido utilizar-se de experimentos alternativos para o ensino do curso de engenharia?; (b) Questão 2: Considerando as atividades realizadas na disciplina, o que foi considerado mais relevante: o uso dos materiais alternativos ou os experimentos industrializados?; (c) Questão 3: O uso dos experimentos com materiais alternativos realizados na disciplina colaborou para a mudança de sua visão em relação ao uso destes materiais para a aprendizagem no curso de engenharia?

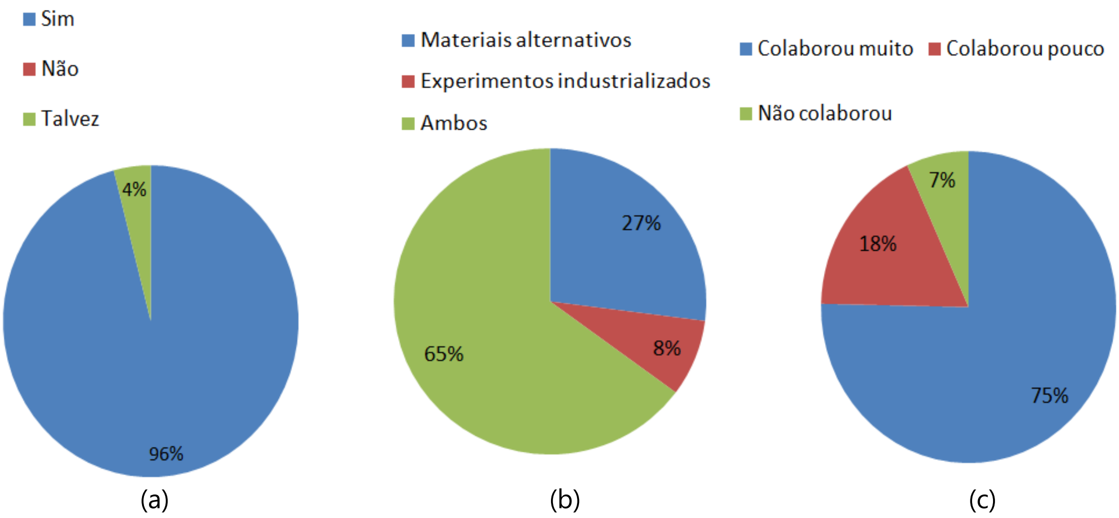

Figura 5. Resultados do questionário aplicado aos discentes que cursaram a disciplina.

Ao término da disciplina, como avaliação final os alunos deveriam redigir um artigo referente ao projeto apresentado, entre estes houve duas publicações no COBENGE 2012, (TEIXEIRA *et al.*, 2012 e BOFF *et al.*, 2012) e o aceite de três resumos e CONEM 2012.

4 Conclusão

Durante o desenvolvimento da metodologia pode se destacar principalmente o desenvolvimento de habilidades e competências aos tutores e discentes.

O papel dos tutores foi induzir o processo de aprendizagem, orientando os alunos da disciplina com diretrizes para concepção do projeto e avaliar a relevância e aplicabilidade do projeto desenvolvido na data estipulada. Assim, para os tutores, o uso da metodologia proporcionou o desenvolvimento de habilidades como criatividade, eloquência, senso crítico, que contribuem para uma postura pró-ativa perante os problemas a serem solucionados, visto que os mesmos deveriam orientar os alunos na definição e execução dos projetos pelos discentes da disciplina, fornecendo feedbacks sobre a relevância dos temas que cada equipe propunha no início do cronograma de atividades. Adicionalmente, desenvolveram-se habilidades de planejamento e controle, das quais dependem o êxito da atividade.

Vale salientar que o papel do professor foi essencial no acompanhamento e na orientação dos tutores, tanto ao sugerir contextualizações na fase de planejamento quanto ao avaliar o desempenho dos tutores durante e após cada aula. No entanto, deve haver algumas precauções a serem tomadas pelos professores para que os mesmos não tenham uma atitude passiva durante o desenvolver da metodologia. A principal delas diz respeito ao tempo necessário para o acompanhamento dos projetos desenvolvidos pelas equipes, pois o acompanhamento das atividades dos discentes requeria maior parcela de tempo aos tutores, não sendo suficiente o tempo reservado durante parte das aulas. Para superar esta dificuldade, era necessária a intervenção do professor, sobretudo nos horários extraclasse.

Para os discentes foi apresentado um novo processo de ensino/aprendizagem que contribuiu na busca de possíveis soluções de problemas equivalentes aos encontrados na vida profissional através do conteúdo da disciplina e até mesmo interdisciplinar.

O contato direto com tutores que também eram alunos, também contribuiu para discussões construtivas de maneira descontraída, que motivaram a mudança de comportamento e a visão dos discentes em relação ao interesse pelo conteúdo abordado na disciplina. Sem mencionar que a utilização do PBL e a produção científica como parte da avaliação, permitiu o desenvolvimento de habilidades e competências proporcionando reconhecimento acadêmico e profissional.

De maneira transversal, além dos conceitos físicos previstos na ementa da disciplina foram abordadas questões socioambientais com a utilização de materiais de baixo custo para execução dos experimentos. Fato que proporcionou um novo olhar quanto a utilização destes matérias no ensino de engenharia e quanto a questões ambientais pelo fato do material não ter o destino do lixo comum.

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IJCLEE/PAEE'2015 Full Papers Submissions (Spanish)

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Project-Based Learning to Promote Social Responsibility in Engineering Students

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Abstract

A set of multidisciplinary integration projects has been held at the Polytechnic School of the European University of Madrid in the year 2013-2014: this new philosophy of work at School has been called "Project Based Engineering School" (PBES). All the students developed an entire project over several subjects in each course of every degree. In this scenario the proposal of this article is developed. This article deals with two different projects into a common line of Social Commitment and Cooperation for Development, both projects highlighted among the PBEs in the Telecommunications Degrees and Computer Engineering Degree. Let us remark that there was a competition at the Polytechnic School at the end of the course, where two groups of students presented their work in the quoted projects and won first and second prize in the ICT Area.The description of the projects and their learning objectives is exposed along the article, as well as the activities and tasks of the involved subjects. Generic skills acquired with its evaluation system based on rubrics are set. In the results section the student projects that won the award are presented.

Keywords: project-based learning; social responsibility; Software Engineering; Telecommunications.

Aprendizaje Basado en Proyectos para Fomentar el Compromiso Social en Estudiantes de Ingeniería

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Abstract

En el curso 2013-2014 se realizaron en la Escuela Politécnica de la Universidad Europea de Madrid, un conjunto de proyectos integradores multidisciplinares formando parte de una nueva filosofía de trabajo en la escuela que se ha dado en llamar "Project Based Engineering School" (PBES). En cada curso de cada titulación los alumnos desarrollen un proyecto completo a lo largo de varias asignaturas. En este escenario se desarrolla la propuesta de este artículo.

Dentro de las titulaciones de Telecomunicaciones e Informática destacaron sendos proyectos integradores dentro de una línea común de Compromiso Social y Colaboración al Desarrollo. Cabe destacar que al finalizar el curso hubo un concurso en la Escuela Politécnica de la UEM, donde dos grupos de alumnos presentaron sus trabajos y obtuvieron el primer y segundo premio en el Area TIC.

En este artículo se describen los objetivos de aprendizaje delos proyectos, se exponen las actividades y tareas de las asignaturas y se enuncian las competencias genéricas adquiridas con su sistema de evaluación en base a rúbricas. En el apartado de resultados se presentan los proyectos de los alumnos que ganaron el premio mencionado.

Keywords: Responsabilidad Social; Cooperación al Desarrollo; Desarrollo Competencial; Aprendizaje Basado en Proyectos.

1 Introducción

El compromiso social debe formar parte de la educación de nuestros jóvenes, tanto en la escolarización básica como en la universitaria, ya que esta formación en valores genera ciudadanos mejor preparados y más comprometidos con la sociedad. Para acometer las tareas a las que se enfrentaran a lo largo de su vida profesional es muy importante que sean conscientes de las desigualdades que existen nuestra sociedad, con el fin de que puedan introducir elementos de sostenibilidad en los proyectos en los que trabajen. En este trabajo se describen dos escenarios en dónde en los que el compromiso social es el factor clave de los proyectos: En el Grado en Ingeniería de Sistemas de Telecomunicación, el proyecto consiste en intentar dar una solución al problema de la detección de agua no potable en pozos de áreas rurales de un país latinoamericano, mientras que el proyecto del Grado en Ingeniería Informática pretende ayudar a organizaciones que luchan contra la lacra de la violencia machista.

1.1 Motivación

En el mundo global en el que vivimos, el 97% de las personas que nacen lo hacen en países empobrecidos (Estado de la Población 2011), y sólo una pequeña proporción de la población total del planeta vive en una sociedad desarrollada, en el llamado estado del bienestar y hemos de ser conscientes de que nuestra realidad es una parte mínima de una realidad mayor donde las condiciones de vida son mucho más duras, es más, en nuestros países desarrollados son muchos los colectivos y las personas con serios problemas de integración, de salud y que sufren la violencia y la marginación. Es importante que desde la Universidad se desarrolle una labor de sensibilización ante la necesidad de otros colectivos desfavorecidos e inculcar principios o valores como la solidaridad y el compromiso social que tenemos la obligación no sólo de inculcar en los estudiantes que deben de ser conscientes de su posición privilegiada, sino que debemos desarrollar actividades académicas con proyectos reales que propongan en implanten pequeñas soluciones a los problemas de colectivos más vulnerables. Dentro de las ingenierías relacionadas con las tecnologías de la información y las comunicaciones se abren infinitas posibilidades para que el estudiante pueda desarrollar una labor solidaria y comprometida mediante la implantación de soluciones técnicas que ayuden a paliar necesidades básicas, prevenir problemas de salud en otros países en vías de desarrollo o que permitan ayudar a colectivos vulnerables de nuestra sociedad occidentalizada.

A tenor de esta realidad social que podemos encontrar tanto a nivel nacional, como a nivel supranacional, nos propusimos introducir en las titulaciones de Informática y Telecomunicaciones elementos de sostenibilidad curricular que potencien el compromiso social de nuestros estudiantes.

En este artículo vamos a describir dos proyectos realizados en la Universidad Europea de Madrid en los que el compromiso social supone el eje central que guía los proyectos. El proyecto que presentaremos en el Grado en Ingeniería de Sistemas de Telecomunicación, con un enfoque más internacional, está orientado a proponer una solución técnica a un problema de detección de agua no potable en un país latinoamericano, mientras que el proyecto del Grado en Ingeniería Informática se centra en intentar ayudar a corregir uno de los grandes problemas de desigualdad social que tenemos a nivel nacional: el machismo y la violencia de género.

1.2 Escenario académico: la Project Based Engineering School de la UEM

Estos proyectos se han desarrollado bajo el paraguas académico de la Project Based Engineering School (PBES), un enfoque pedagógico que ha adoptado la Escuela Politécnica de la Universidad Europea desde el curso 2012/2013, y que consiste en la aplicación de Aprendizaje Basado en Proyectos (ABP) en todos los grados y cursos de la Escuela. Los estudiantes de Ingeniería desarrollan en cada curso un proyecto integrador que cubre los contenidos de varias asignaturas (normalmente entre dos y cuatro). Dicho Proyecto, además de integrar los contenidos de varias asignaturas y de involucrar a varios profesores en su gestión y desarrollo, también cuenta normalmente con la colaboración de una empresa o un organismo que aporta el punto de vista del mundo extracadémico, algo que los estudiantes valoran muy positivamente (García2014).

En el apartado dos de este artículo se expondrán, los objetivos de aprendizaje de los estudiantes, organización de las asignaturas y actividades académicas desarrolladas en cada de dos de los proyectos desarrollados dentro de la citada escuela PBEs en el curso 2013-2014, no obstante introduzcamos brevemente dichos proyectos que se relacionan por desarrollar competencias y valores en los estudiantes como son la solidaridad, la cooperación al desarrollo y la responsabilidad y el compromiso social:

Diseño y Análisis de Sistema de Comunicación Pozos-PC (2º del Grado en Ingeniería de Sistemas de Telecomunicación):

El objetivo final del proyecto integrador es realizar el diseño completo del sistema electrónico, informático y de radiocomunicación sobre un entorno geográfico en una zona en vías de desarrollo para emular el establecimiento y optimización de un sistema de que permitirá comunicar los pozos de agua de uso de la población con la sede central en una ONG con el objeto de emitir automáticamente señales de alarma en caso de agua no potable.

Observatorio digital de Violencia de Género (3º del Grado en Ingeniería Informática):

El proyecto ha consistido en crear un sistema que descarga todos los días noticias periodísticas de diversos medios de comunicación nacionales y las clasifica de forma automática, detectando qué noticias tratan un caso de violencia machista. Posteriormente esas noticias se procesan buscando patrones de comportamiento con el fin de mejorar las campañas de prevención de violencia doméstica.

1.3 Antecedentes

Ya en cursos anteriores se han realizado experiencias en el aula que han sido precursoras o que han servido como punto de partida para avanzar y mejorar cada uno de los dos proyectos que competen a este artículo:

Algunas de ellas versaban sobre proyectos integradores (PBES) dentro del área de telecomunicación donde se implicaban varias asignaturas, dichos proyectos consistían en el diseño e implantación por parte de los alumnos de diferentes sistemas de telecomunicación de radiofrecuencia en zonas en vías de desarrollo (Blanco2011, Blanco2012, Blanco2013) en el curso 13-14 esas experiencias han servido para proponer un proyecto PBES más completo y complejo con más asignatura implicadas abordando no sólo la radiofrecuencia, sino también la electrónica y la programación de los equipos transmisores y receptores, tal y como se describirá en el apartado 2.

Dentro del área de Informática, otros proyectos que se han abordado anteriormente versaban sobre el uso de sistemas de minería de datos y conocimiento extraído de la web semántica para enriquecer de forma automática textos de blogs y noticias periodísticas.

2 Descripción de los procesos de aprendizaje

En este apartado se describen los dos proyectos de carácter social e integrador (por integrar conocimientos de varias materias) sobre los que versa este artículo, tal y como venimos diciendo uno de ellos orientado a la cooperación al desarrollo que pretende dar una solución técnica a un problema de detección de agua no potable en una zona subdesarrollada y el otro orientado al compromiso y la responsabilidad social y que pretende colaborar con la prevención de la violencia de género en un país desarrollado.

2.1 Definición de los proyectos y sus objetivos

2.1.1 Títulos, cursos, asignaturas

- Titulación: Grado en Ingeniería de Sistemas de Telecomunicación y Grado en Ingeniería de Sistemas Audiovisuales de Telecomunicación.
- Curso: 2º
- Título del proyecto: Sistema de Telecomunicación Pozos-PC vía RF para detección de agua no potable en zona en vías de desarrollo
- Asignaturas que integra: Emisión y Recepción, Programación Multimedia, Digital Electronics and Microprocessors, Comunicaciones Analógicas y Digitales.
- Titulación: Grado en Ingeniería Informática.
- Curso: 3º
- Título del proyecto: Observatorio digital de violencia de género
- Asignaturas que integra: Inteligencia Artificial, Programación concurrente y Sistemas Distribuidos, Interfaces de Usuario.

2.1.2 Descripción y Objetivos de aprendizaje

En el proyecto integrador de telecomunicación que se ha enunciado en el apartado anterior: Los estudiantes en grupos de trabajo diseñaron el sistema completo que permitirá comunicar los pozos de agua de la aldea Cerro Verde (en la región de Choluteca en Honduras) con la sede central de la ONG "Fundación Cerro Verde" en la misma aldea, con el objeto de emitir automáticamente señales de alarma en el caso de agua no potable mediante el uso de un sistema integrado que incluía los sensores en los pozos, microprocesador para la gestión de señales, sistema RF para transmisión de información y aplicación multimedia en la ONG para interpretación y gestión de la información de los pozos.

El objetivo global de aprendizaje que alcanzan los estudiantes a desarrollar entre las actividades de todas las asignaturas implicadas es:

- Aprender a diseñar el sistema electrónico, informático y de telecomunicación sobre un entorno geográfico en una zona en vías de desarrollo para emular el establecimiento de un sistema de detección de agua no potable en los pozos de abastecimiento de la población.

Para alcanzar este objetivo global los estudiantes cubren otros objetivos intermedios de aprendizaje en cada asignatura:

- En la asignatura Electrónica: Adquirir habilidades para montar un sistema formado por sensor-arduino- placa "wifi" - antena RF y comunicación RF con PC y Aprender a configurar microprocesadores para detectar la señal enviada por el sensor sumergido y enviarla vía WIFI.

- En la asignatura de Programación: Desarrollar un programa gráfico que permite abrir un puerto en el PC y mostrar los resultados y señales de alarma de forma gráfica.
- En la asignatura de Emisión y Recepción: Realizar simulaciones de radio y calculan parámetros de radiofrecuencia como ruido y cobertura.
- En la asignatura de Comunicaciones Analógicas y Digitales: Analizar el tipo de modulación digital utilizada en la comunicación pozo –PC y calcular sus prestaciones, además integrar los resultados de todas las asignaturas para escribir una memoria única.

Por otro lado, el proyecto integrador del grado en informática los estudiantes han creado un "Observatorio Digital sobre Violencia de Género", que consta de un sistema que descarga todos los días noticias periodísticas de diversos medios de comunicación nacionales (El País, El Mundo, ABC, ...) y las clasifica de forma automática, detectando qué noticias tratan un caso de violencia machista. De esta forma se evita que una persona tenga que leer todas las noticias y secciones de cada periódico, disminuyendo por tanto el tiempo necesario para encontrar noticias relacionadas con el tema.

El objetivo global del proyecto integrador conseguido por los estudiantes ha sido:

- Generar una colección de datos de noticias de los últimos 10-15 años, utilizar dichos datos para crear un modelo que clasifica automáticamente noticias nuevas, permitiendo buscar y detectar patrones en los casos de violencia de género.

El uso de los resultados de la herramienta diseñada por los estudiantes permitiría diseñar campañas de formación y prevención dirigidas a aquellos sectores de la población que coinciden con dichos patrones.

Dicho objetivo global se consigue mediante el alcance de otros objetivos de aprendizaje secundarios:

- Desarrollar un sistema informático que clasifique las noticias relacionadas con violencia de genero de forma automática, realizar la transferencia de información a otro sistema que permita a una persona extraer mediante un programa informático una serie de atributos relevantes del caso.
- Diseño e implementación de la herramienta que recoge los siguientes atributos: fecha, el tipo de violencia (doméstica, no doméstica) (Feminicidio, matricidio, Filicidio,...), fuente de la noticia, nombre y edad de la víctima, relación entre agresor-victima (matrimonio, compañero, amante, ex-compañero, ex-marido,...), tipo de arma utilizada (blanca, de fuego, con las manos,...), nacionalidad víctima y del agresor, sus niveles de estudios, etc.

2.2 Coordinación, Cronogramas y tareas

Dado que son varias las asignaturas implicadas en cada uno de los dos proyectos se hace necesaria e imprescindible la coordinación de tareas y actividades en el aula en tiempo, espacio y forma, siendo un necesario un profesor coordinador que revise y gestione todo el proceso guiado por los diferentes profesores en sus asignaturas. Es necesaria una definición y una planificación de tareas asociadas a cada asignatura. Después son necesarias reuniones de coordinación entre profesores para el establecimiento de las fechas en que se van realizando las diferentes actividades de forma coordinada. A continuación se enumeran las actividades y tareas asociadas a las mismas en las asignaturas implicadas.

2.2.1 Sistema de Telecomunicación Pozos-PC:

- **Emisión y Recepción:**
  - Búsqueda y estudio de características y prestaciones de equipos de radiofrecuencia: antenas, transmisores y receptores necesarios
    - Calculo de enlace radiofrecuencia.
    - Calculo de potencia de ruido en recepción.

- Electrónica Digital y Microprocesadores:
  - Conexión (y puesta en marcha) del prototipo sensor-arduino y módulo wifi
    - Montaje, configuración de prototipos y realización pruebas.
    - Envío y gestión de señales de alarma por microprocesador.

- Programación Multimedia:
  - Aplicación con interfaz sencillo de manejo de incidencias.
    - Procesar la información procedente de los pozos.
    - Hacer un seguimiento de su estado general.
    - Detectar e informar de manera activa ante posibles incidencias.
- Comunicaciones Analógicas y Digitales:
  - Cálculos de cobertura, BER calidad y distribución del espectro
  - Conclusiones , integración y cierre de la memoria del proyecto
  - Exposición del proyecto completo

2.2.2 Observatorio Digital de Violencia de Género

- Inteligencia Artificial:
  - Creación de un clasificador automático de noticias periodísticas
    - Diseño y creación de la colección de datos de noticias.
    - Proceso de Aprendizaje automático para crear un reconocedor inteligente de noticias que tratan violencia de género.

- Programación Concurrente y Sistemas Distribuidos:
  - Generación del servicio web
    - Diseño y programación de una API para la comunicación de datos entre el programa cliente y el servidor.

- Interfaces de Usuario:
  - Aplicación con interfaz sencillo de manejo de incidencias
    - Diseño de una aplicación de escritorio (para entorno Windows) para la extracción de los atributos de cada noticia.
    - Diseño de una aplicación web para visualizar de forma gráfica las estadísticas y patrones de violencia.

2.3 Competencias genéricas adquiridas y su evaluación

La propia naturaleza de los proyectos permite desarrollar en el alumno que trabaja de forma intensa aplicando los conocimientos adquiridos a proyectos prácticos reales la adquisición de las competencias técnicas o específicas establecidas en las memorias oficiales de los grados. La evaluación de las competencias técnicas se realiza en función de la calidad del entregable escrito asociado a la memoria del proyecto entregado por cada grupo de alumnos.

Por otro lado la idiosincrasia solidaria de los proyectos en los que se ve implicado de forma activa e intensa, así como la colaboración entre compañeros para sacar adelante un proyecto con un prototipo funcionando y una descripción exhaustiva del mismo en la memoria desarrolla sin duda competencias generales de la profesión reflejadas en las memorias de los títulos , competencias como el desarrollo de proyectos, la búsqueda y gestión de información, el aprendizaje autónomo, las habilidades comunicativas de conocimientos técnicos y el trabajo en equipo. Para evaluar el nivel de adquisición de dichas competencias el profesor usa como herramienta rúbricas como la siguiente que permiten medir de forma cuantitativa a cada estudiante.

Dada la limitación de espacio y a modo de ejemplo se muestra a continuación la rúbrica de evaluación de una de las competencias evaluadas en uno de los proyectos:

Tabla 1: Rúbrica ejemplo de evaluación de una de las competencias genéricas de la profesión desarrolladas:" Capacidad para redactar y desarrollar proyectos en el ámbito de su especialidad"

INDICADORES	1	2	3	4
Corrección del planteamiento del problema o necesidad a solventar	Tras una lectura detallada y atenta : No se llega a saber cuál es el objeto ni la situación de partida a solucionar	Algún aspecto, o exposición del planteamiento es correcto y se entiende. Pero hay carencias en los contenidos que se han de exponer	Se comprende casi todo, salvo algún aspecto más complejo que ha quedado confuso o ausente. Los contenidos son adecuados para comprender el alcance del problema	Tras la lectura detallada y atenta, se comprende todo el problema en cuanto a estado de la situación, requisitos, necesidades a cubrir, objetivos del proyecto.
Análisis Práctico o Resultados Experimentales	Los resultados experimentales aportados no son correctos, se echan en falta muchos de ellos.	Sólo se entienden bien algunos contenidos experimentales. Faltan la mayoría de las explicaciones o el análisis de los resultados	En el documento están bien casi todos los resultados experimentales y están bien argumentados. Algunas explicaciones son mejorables	Todos los resultados experimentales son correctos y están bien argumentados o explicados apoyándose en contenidos teóricos expuestos
Propuesta Final y Conclusiones	No se ve cual es la propuesta final ni la solución al problema.	La propuesta de la solución con su viabilidad es confusa en ciertos aspectos. No quedan del todo claras las alternativas posibles con ventajas e inconvenientes de cada ni quedan claros las fases de implementación de la propuesta, equipos y/o presupuestos.	La propuesta de la solución con su viabilidad queda bastante bien expuesta y clara salvo algunos aspectos menores. Quedan más o menos claras las alternativas posibles y las fases de la implementación salvo algunos detalles confusos.	La propuesta de la solución con su viabilidad queda bien expuesta y clara. Quedan claras las alternativas posibles con ventajas e inconvenientes de cada una si ha lugar. Quedan claras las fases de implementación de la propuesta, los equipos y presupuestos.

3 Resultados

Para medir los resultados contamos con dos medidas: Cuestionarios para evaluar la satisfacción de los estudiantes, y una evaluación externa por parte de empresas afines al área de las TIC, que seleccionaron los mejores proyectos de la Escuela en un concurso organizado a final de curso. En los cuestionarios se preguntaba a los estudiantes sobre distintos aspectos del desarrollo del proyecto a lo largo del curso académico, y en él se incluyeron dos preguntas para ver su valoración sobre los aspectos sociales del proyecto. Concretamente se les pidió que valoraran (en una escala de 1 a 5) el hecho de incluir temas de responsabilidad social como eje central de los proyectos, y que valoraran de 1 a 5 la afirmación de que la temática del proyecto ha ayudado a tomar conciencia sobre el problema social que se planteaba. La primera pregunta los estudiantes la valoraron con una media de 4,6, mientras que la segunda tuvo una ponderación media de 5.

Por otro lado, a finales de junio de 2014 desde la Escuela Politécnica se lanzó un concurso para los alumnos en el cual se premiaban los mejores PBEs realizados por los estudiantes de la escuela en cada una de las áreas de ingeniería de la misma. En dicho concurso fue un tribunal formado por profesionales externos a la UEM el que valoró la calidad y premió a los mejores en función de los videos que realizaron y mostraron los propios alumnos.

Previamente a la fase final del concurso que acabamos de exponer, se hizo la siguiente selección previa: los profesores seleccionaban los mejores proyectos de alumnos y les pedían preparar su candidatura en base a la elaboración de cierta documentación pedida, después un tribunal formado por miembros de la junta de la escuela revisaban esa documentación y seleccionaban los candidatos que podían presentarse al concurso. Los candidatos prepararon sus videos y dentro del área TIC los dos grupos premiados fueron grupos de alumnos de los dos proyectos sobre los que versa este artículo. Los videos se pueden visualizar en:

http://politecnica.universidadeuropea.es/escuela/noticias/147/Proyecto-Integrador-2014-PBES:-Diseño-y-análisis-de-un-sistema-de-comunicación-pozos---PC--para-detección-de-agua-no-potable y en http://politecnica.universidadeuropea.es/pi/violencia-genero/

4 Conclusiones

Como conclusión de esta experiencia podemos reflejar que la inclusión de temas de responsabilidad social en proyectos de ingeniería ayuda a los estudiantes a potenciar valores sociales necesarios para el desempeño sostenible de su profesión en el futuro. Además de eso, estudiantes y empresas han visto de forma muy positiva dicha inclusión. En resumen podemos decir que la combinación de Aprendizaje Basado en Proyectos en Grados de ingeniería, con temas de responsabilidad social y sostenibilidad curricular presenta las siguientes fortalezas:

- Se trata de proyectos que fomentan valores importantes como la Responsabilidad Social, el compromiso con los sectores más desfavorecidos de la sociedad global y la labor social del ingeniero.

- La realización de estos proyectos en el aula a lo largo de las asignaturas implicadas ha contribuido a reforzar las competencias técnicas adquiridas en el proceso de aprendizaje mediante el diseño, montaje, codificación, estudio y análisis de sistemas reales de laboratorio. Dichos sistemas aunque son prototipos, sí que suponen un punto de partida y se acercan bastante a lo que sería un desarrollo real para una empresa u organización.

- El desarrollo de competencias transversales tales como la búsqueda de información, la resolución de problemas, la comunicación oral y escrita es innato a la propia metodología de trabajo colaborativo. Se desarrollan y evalúan estas competencias en las asignaturas implicadas.

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Participation of a Company in the Service Sector in the Semester Project: a Case Study

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Abstract

This research addresses the development, outcomes and project evaluations obtained in the first semester of Master in Business Innovation and Project Management of Mondragon Unibertsitatea. Problem Oriented Project Based Learning (onwards POPBL) is the methodology used during this period and specifically, the problem is focused on a real organization of service sector.

The mission of the company is to integrate disabled people in a work environment. The project is focused on the catering service the company offers to different groups. In the coming years the company expects to increase demand by 60%. However, the facilities do not have enough capacity to respond to this new scenario. Given this situation, it exists a great business opportunity that can provide a differential value, increased infrastructure capacity. Students propose a solution that provides the necessary operational, economic and social requirements. Communication between students and the company is continuous and direct throughout the project.

POPBL management is performed through the agile philosophy, more precisely through the Kanban method. The project has three consecutive milestones. In the first and second milestones, the group provides the operational framework; size and define the necessary facilities; determine the operational work and workflow; as well as the supply chain from suppliers to customers. Furthermore in the social field, the project develops a system of processes that allows the inclusion of disabled people with lower profiles. Finally, it analyses the cost structure and evaluates the feasibility of the proposed solution. In the last milestone, in the act of completion of the project, students present the achievements to the company and to the faculty

Keywords: active learning; POPBL; University-Industry collaboration.

Participación de una Empresa del Sector Servicios en el Proyecto de Semestre: Estudio de un Caso

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Resumen

La presente investigación aborda el desarrollo, los resultados y las valoraciones obtenidas en el proyecto del primer semestre del Máster Universitario en Innovación Empresarial y Dirección de Proyectos de Mondragon Unibertsitatea. Se trabaja el aprendizaje basado en problemas, "Problem Oriented Project Based Learning" (en adelante POPBL), y en concreto, en este caso se trabaja un problema real de una organización enmarcada en el sector de servicios.

La empresa tiene como misión la integración al mundo laboral de personas con discapacidad y el proyecto se centra en el servicio de restauración que esta ofrece a diferentes colectivos. En los próximos años prevé aumentar la demanda un 60%. Sin embargo, las instalaciones de las que dispone no tienen capacidad suficiente para responder a este nuevo escenario. Ante esta tesitura, se observa una gran oportunidad de negocio que puede otorgar un componente diferencial: el aumento de capacidad de las infraestructuras. Los alumnos proponen una solución que contempla los requisitos necesarios en los ámbitos operativo, económico y social. Cabe destacar que la comunicación entre alumnos y empresa es continua y directa a lo largo del proyecto.

La gestión del POPBL se realiza a través de la filosofía ágil, concretamente mediante el método Kanban. El proyecto mantiene tres hitos consecutivos. En el primer y segundo hito, el grupo establece el marco operativo; dimensiona y define las instalaciones necesarias; determina la operativa y el flujo de trabajo y define la cadena de suministro desde proveedores a clientes, en el ámbito social, desarrolla un sistema de procesos que permite la incorporación de personas con perfiles de discapacidad más bajos y analiza la estructura de costes evaluando la viabilidad de la solución planteada. En el último hito, los estudiantes presentan los logros conseguidos a la empresa y al profesorado en el acto de culminación del proyecto.

Palabras clave: aprendizaje activo; POPBL; colaboración Universidad-Industria.

1 Introducción

Durante las últimas décadas, el aprendizaje basado en la formulación de problemas y organizado a partir de un proyecto ha ganado terreno dentro de los estudios de educación superior (Kolmos, 2004). Desde el año 2000 Mondragon Unibertsitatea ha venido utilizando la metodología de aprendizaje basada en proyectos "Project Based Learning" o "Problem Oriented Project Based Learning" (en adelante POPBL) (Markham, 2003) (Lehmann, Christensen, Du, & Thrane, 2008) en todas y cada una de sus titulaciones. Para todas las instituciones de enseñanza superior, el modelo de enseñanza basado en proyectos resultó ventajoso para el aprendizaje y la adquisición de competencias de los estudiantes (Kolmos, 2004), siendo de igual manera para Mondragon Unibertsitatea en todas sus experiencias anteriores.

Teniendo en cuenta la estrecha relación que mantiene al mundo de la industria Mondragon Unibertsitatea, que posibilita que los alumnos conozcan la realidad laboral desde el inicio de los estudios a través de prácticas en empresa o proyectos fin de carrera, este artículo, trata de demostrar cómo el aprendizaje basado en proyectos orientado a los problemas de una empresa concreta proporciona beneficios a los estudiantes, profesores y empresas (Lehmann, Christensen, Du, & Thrane, 2008). El artículo en primer lugar analiza la descripción del proyecto: problemática de la empresa, objetivos a cumplir en cada una de las asignaturas participantes en el proyecto, hitos representativos, así como la gestión del proyecto y la evaluación del mismo. En segundo lugar muestra los resultados obtenidos de la experiencia: las valoraciones de los interesados tras diversas encuestas, como los resultados académicos obtenidos y la comparativa de estos con años anteriores donde no se integró a la empresa en el POPBL. Se ha llegado a la conclusión de que, el aprendizaje basado en proyectos y en problemáticas de una empresa concreta puede potenciar conocimiento más profundo de las competencias específicas.

2 Descripción del Proyecto del Semestre

El POPBL está enfocado en el primer semestre del Máster Universitario en Innovación Empresarial y Dirección de Proyectos de Mondragon Unibertsitatea, en el cual se trabajan contenidos en torno al ámbito de la organización industrial. Concretamente las asignaturas que se abordan en este primer semestre son las siguientes: Estadística avanzada para la empresa, Ingeniería de producción, Operaciones para directivos, Contabilidad y finanzas para directivos y Gestión de proyectos.

Teniendo en cuenta la naturaleza del semestre y la convicción de plantear el problema en la industria actual, se ha enfocado el proyecto en una organización real enmarcada en el sector de servicios, en particular en el servicio de la restauración. La empresa mantiene como uno de sus principales valores la inserción de personas con discapacidad al mundo laboral, con lo que se destaca el ámbito social del proyecto.

2.1 Planteamiento del Problema

La organización dispone de instalaciones propias en las cuales ofrece servicio de restauración a colectivos muy dispares, desde universidades hasta centros de día para personas mayores. Además, la empresa ofrece servicio a domicilio. Existen evidencias reales de crecimiento de la demanda actual donde se prevé aumentar la actividad en ambos servicios. En la actualidad la cuota de mercado de la empresa apenas alcanza el 1% del posible mercado de Gipuzkoa. Con todo ello, se estima que la demanda prevista para los próximos años pueda alcanzar una cuota del 60% superior a la demanda actual.

Asumiendo dichas cifras, queda latente que la capacidad de las instalaciones actuales es insuficiente, ya que hoy en día apenas llegan a abastecer su demanda. Por ello, se ha adquirido un nuevo pabellón con el doble de espacio donde poder satisfacer la demanda prevista para los próximos años; previendo un aumento de la capacidad productiva y la incorporación de nuevas personas. Bajo esta tesitura se han planteado de manera general los siguientes objetivos;

i. Poner en marcha una cocina industrial que sea capaz de ofrecer 3.700 comidas/día.
ii. Desarrollar un sistema de procesos que permita la incorporación de personas con diferentes grados de discapacidad.
iii. Incorporar paulatinamente personas ocupacionales al proceso productivo.

Además, existen una serie de objetivos que se han de cumplir relacionados a las distintas temáticas trabajadas durante el primer semestre del Máster, como se pueden ver en la Tabla 1. a excepción de la asignatura de Gestión de proyectos que se muestra en el apartado 2.2. de este artículo.

Tabla 1: Objetivos parciales por asignaturas

Asignatura	Objetivos
Estadística avanzada para la empresa	i. Definir la demanda a atender en los próximos cinco años mediante una serie temporal analizando la tendencia de la serie y realizando predicciones.
Ingeniería de producción	i. Determinar los recursos materiales necesarios para satisfacer la demanda. ii. Dimensionar la superficie necesaria para cada uno de los recursos. iii. Determinar los recursos personales necesarios para satisfacer la demanda, teniendo en cuenta la necesidad de incorporar personas con discapacidad. iv. Determinar la operativa de trabajo y el flujo de materiales. v. Definir la distribución en planta del proceso productivo.
Contabilidad y finanzas para directivos	i. Determinar la estructura de la empresa que se va a formar, el activo necesario y la correspondiente financiación. ii. Analizar la estructura de costes del producto a fabricar. iii. Obtener un plan de negocio a cinco años, las cuentas de resultados previsionales y el presupuesto de tesorería. iv. Evaluar la viabilidad económica de la inversión.

Tabla 2: Objetivos parciales por asignaturas (Continuación)

Asignatura	Objetivos
Operaciones para directivos	i. Definir la gestión de stocks y materiales. ii. Identificar los proveedores existentes para los productos de compra indicando el lote mínimo y el plazo de aprovisionamiento para cada uno de ellos. iii. Descripción física y operativa de la cadena de suministro desde proveedores a clientes. a. Identificar los envases y embalajes a utilizar para cada una de las materias primas (tipología, medidas). b. Definir la distribución en planta del almacén necesario. c. Dimensionar los recursos necesarios para las funciones de recepción, almacenamiento y suministro a cocina definiendo el procedimiento de actuación para cada uno de los casos. d. Establecer la política de stocks de acuerdo a la tipología del producto. e. Definir elementos de almacenaje y manutención necesarios en cumplimiento con la normativa de almacenamiento y manipulación de alimentos.

2.2 Gestión del Proyecto e Hitos

La gestión de proyectos es la aplicación de conocimientos, habilidades, herramientas y técnicas a las actividades del proyecto para cumplir a tiempo con los requisitos del mismo (PMI, 2013). El objetivo de la asignatura de Gestión de proyectos es el de realizar una correcta gestión del POPBL a través de la filosofía ágil, concretamente mediante la metodología Kanban. La gestión de proyectos ágil aumenta la capacidad de un equipo para lidiar con el cambio y lo anormal (Highsmith, 2009). También, con el fin de lograr una mejora en la productividad y plazos, resulta clave limitar el trabajo en curso para maximizar el flujo de tareas y conseguir así realizar el trabajo con mayor rapidez. Para el correcto funcionamiento del equipo del proyecto se diseña y establece un tablero Kanban; el tablero permite seguir el grupo de elementos a medida que avanzan a través de un flujo de trabajo bajo los estados de pendiente, en curso y terminado (Kniberg & Skarin, 2010). Además, aunque en el método Kanban no se prescriben gráficos, para el correcto seguimiento y para la identificación instantánea de las desviaciones se constituye un gráfico burndown. El la Figura se puede observar un ejemplo tanto del tablero Kanban como del gráfico burndown. Cabe destacar que para este ejemplo concreto, el trabajo en curso se ha limitado a un total de dos tareas abiertas.

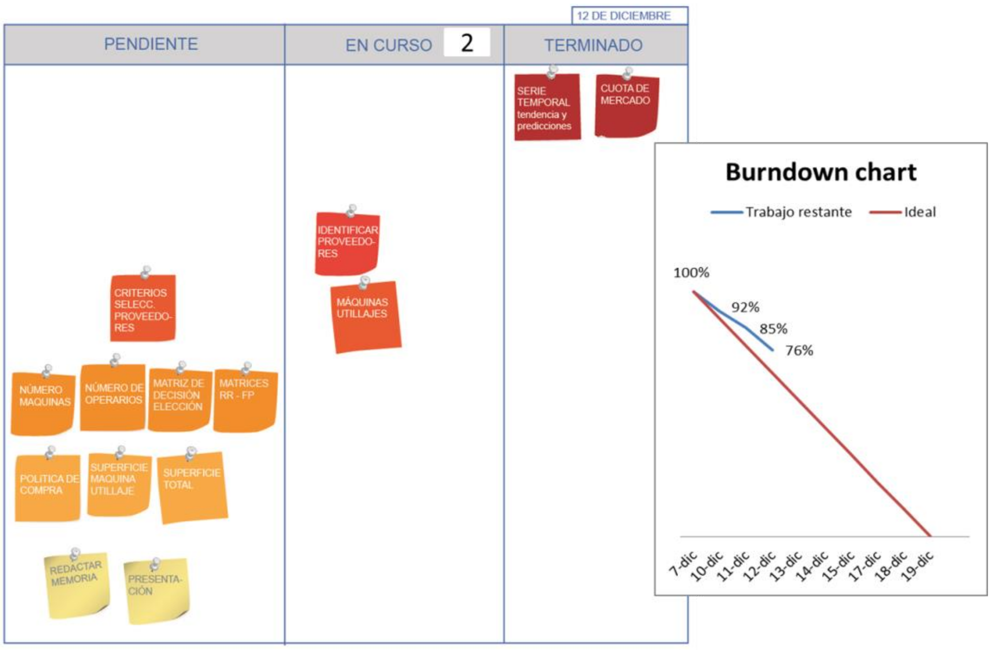


Figura 1: Ejemplo de tablero Kanban y gráfico burndown

El proyecto mantiene tres hitos consecutivos generales y dos hitos intermedios tal y como se muestra en la Figura 2. En el Hito 1, los grupos del proyecto realizan un diagnóstico inicial y extraen las primeras conclusiones. En el Hito 2, diseñan y dimensionan el planteamiento realizado demostrando la viabilidad del mismo. En el Hito 3, los participantes exponen y defienden el trabajo realizado ante el grupo de profesores e interesados de la empresa. En los hitos intermedios, el Hito 0 y el Hito 1.1, se determina la operativa de gestión del proyecto, donde además, se elabora el listado de entregables y tareas para la culminación del próximo hito general. En cada uno de los hitos, tanto en los parciales como en los generales, los alumnos realizan un entregable cumpliendo con los contenidos y características exigidas tal y como se puede observar en la Tabla 3, así mismo reciben una retroalimentación del trabajo realizado por parte del profesorado.

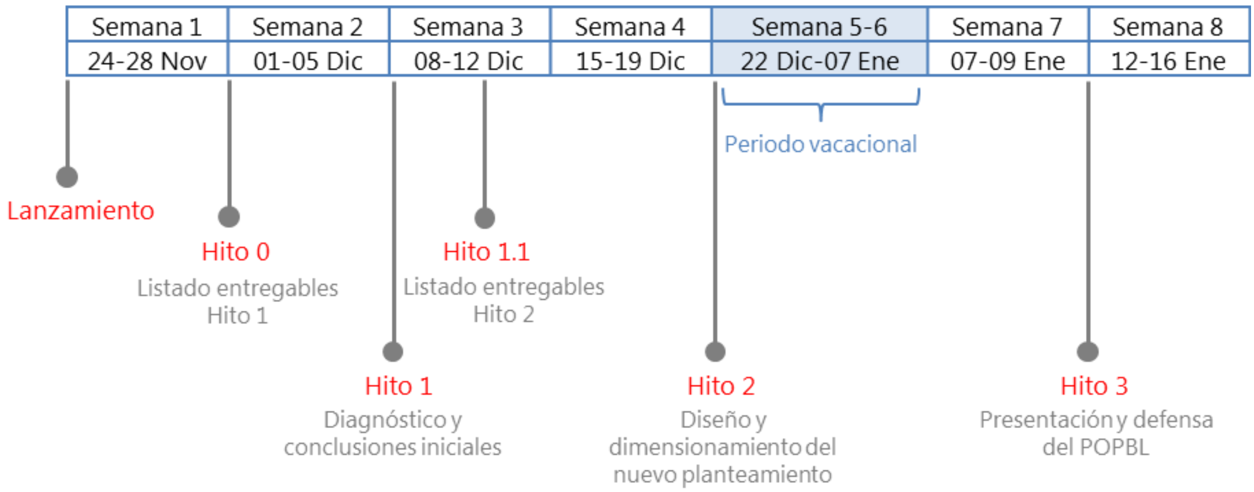


Figura 2: Plan de trabajo

Tabla 3: Contenido de trabajo a realizar en cada uno de los hitos

Hito	Contenido de trabajo	Características entregables
Hito 0	Definición del sistema de gestión del proyecto y diseño del tablero Kanban y gráfico burndown. Listado de los entregables y las tareas a realizar por cada entregable del Hito 1, con la estimación de tiempo y número de personas para realizar la tarea.	Informe escrito.
Hito 1	Análisis de la situación de partida y estimación de la demanda a alcanzar en los próximos años. Determinación de los grupos de producto a desarrollar y definición de los tiempos de fabricación para cada uno de ellos. Establecer la clasificación de comidas a realizar para determinar cada grupo de productos. Identificación de proveedores y las características de cada uno ellos y elaborar el maestro de embalajes y productos. Retrospectiva del trabajo realizado durante el hito 1.	Memoria y Anexos del trabajo realizado durante el Hito 1, con un máximo de 20 hojas.
Hito 1.1	Listado de los entregables y las tareas a realizar por cada entregable del Hito 2, con la estimación de tiempo y número de personas para realizar la tarea.	Informe escrito.

Tabla 4: Contenido de trabajo a realizar en cada uno de los hitos (Continuación)

Hito	Contenido de trabajo	Características entregables
Hito 2	Definición completa de la operativa de trabajo del proceso productivo y el flujo de los materiales, dimensionando tanto recursos materiales como recursos personales. Determinación de la Política de aprovisionamiento. Definición de un plan de negocio a cinco años vista evaluando la viabilidad del planteamiento.	Memoria y Anexos del trabajo realizado durante el Hito 2 con las correcciones sugeridas en el Hito 1 y un máximo de 60 hojas.
Hito 3	Exposición en grupo del trabajo realizado ante el profesorado y personas interesadas de la empresa estudiada.	Presentación de 30 minutos.
	Defensa individual sobre el trabajo realizado en cada una de las asignaturas participantes en el POPBL.	5 minutos de defensa oral.

2.3 Labor de los Tutores y Expertos

Cada uno de los equipos contará con un tutor y un experto en cada una de las asignaturas.

Por un lado, la labor del tutor es la de asesorar al grupo en el desarrollo del POPBL, resolviendo cuestiones generales del proyecto y no sobre contenido técnico. Así mismo, dará la retroalimentación de cada uno de los hitos al grupo correspondiente.

Por otro lado, el tutor de cada uno de los grupos será el nexo de unión entre el equipo del proyecto y los responsables de la empresa. Para ello, cada grupo deberá seleccionar una persona que asuma el rol de comunicador, cuya función será la de trasladar las dudas surgidas durante el proyecto al tutor y éste hará de interlocutor entre el equipo y la empresa. Las dudas se comunicarán a la empresa como máximo dos veces por semana, en concreto, los miércoles y viernes de cada semana. Cabe destacar la importancia de la continua comunicación entre tutor y equipo.

El experto es el profesor responsable de cada una de las asignaturas y su labor es la de resolver dudas técnicas al equipo de trabajo. El experto debe ser convocado con 24 horas de antelación y el máximo de horas para realizar consultas que el equipo puede realizar por cada asignatura asciende a un total de 2 horas.

El formato de tutoría y resolución de dudas se establecerá con cada tutor/experto.

2.4 Evaluación

Se mantiene una evaluación continua a lo largo de todo el POPBL. Gracias a los diferentes hitos marcados los alumnos son capaces de recibir una retroalimentación constante del trabajo realizado por parte del profesorado experto y así mismo, corregir las posibles desviaciones que puedan surgir durante el transcurso del mismo. Esta retroalimentación intermedia no tiene ningún impacto en la nota final, únicamente los alumnos son valorados con la memoria final entregada en el Hito 2, que corresponde al 60% de la nota final, y con la defensa oral realizada en el Hito 3, que corresponde al 40% de la nota final.

3 Resultados Obtenidos

En primer lugar, se han realizado una serie de encuestas a dos de los tres colectivos participantes en el POPBL, alumnado y profesorado, con el fin de conseguir la valoración de cada uno de ellos. La muestra objeto de estudio en el caso de los profesores es de los 5 participantes en el proyecto y en el caso de los alumnos es de los 13 participantes. Para conseguir un mayor grado de exactitud en las encuestas se han amoldado a cada uno de los dos grupos. Se muestra en la Tabla 5 un resumen comparativo de los resultados más relevantes obtenidos.

Tabla 5: Resumen de las encuestas

Cuestión planteada	Escala de valoración	Alumnos	Profesores
El trabajo en equipo aporta aspectos positivos respecto al trabajo individual	de 0 a 5*	4,4	4,8
La metodología POPBL, basada en problemas y proyectos es apta para la asimilación de contenidos técnicos	de 0 a 5	4,4	4,8
Nota global que le doy al proyecto	de 0 a 5	3,8	4
¿Repetirías el proyecto del primer semestre con empresa?	Porcentaje	92% repetiría	100% repetiría

*0 totalmente desacuerdo; 5 totalmente de acuerdo.

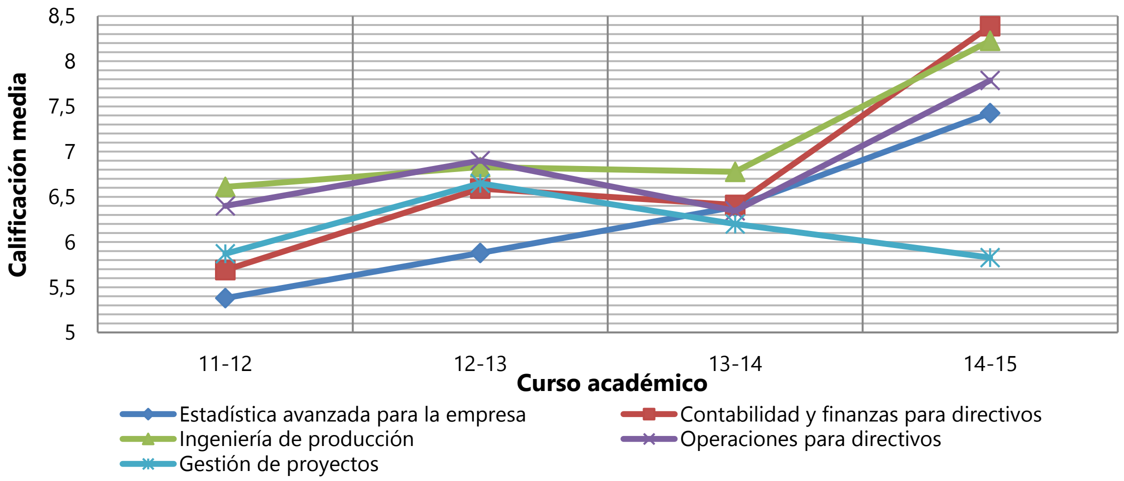
En la Tabla 5 se puede observar que el proyecto ha resultado altamente gratificante en todos los aspectos tanto para el alumnado como para el profesorado. Cabe destacar la alta aceptación por la metodología POPBL y que el 94% del total de los encuestados repetiría el POPBL con la integración de la empresa.

En segundo lugar se han obtenido dos documentos técnicos de gran calidad, con sus correspondientes anexos, dando respuesta a los problemas planteados por la empresa. Los trabajos realizados han dotado de puntos de vista no detectados hasta la actualidad, por lo que las nuevas propuestas planteadas se han valorado positivamente. Así mismo, con las ideas planteadas se prevé triplicar la plantilla de trabajo actual de la empresa, dotando a la empresa con más de un 80% personas con diferentes discapacidades.

Finalmente, destacar que gracias a los resultados obtenidos y con el afán de generar nuevos vínculos entre empresa y universidad, han surgido dos Trabajos Fin de Máster (en adelante TFM) para dar continuidad al trabajo realizado en el POPBL. Los TFM van a ser desarrollados en la empresa en el segundo semestre del Máster por dos alumnos participantes en el proyecto. Por un lado, la finalidad de uno de los TFM es la de desarrollar un estudio de mercado exhaustivo analizando el mercado potencial y adecuando los productos y servicios que se ofrecen a cada uno de los colectivos. Por otro lado, en el segundo TFM se implantará todo el sistema productivo desarrollado en el POPBL, poniendo así en funcionamiento la nueva planta.

3.1 Aprendizaje del Alumno

Desde el punto de vista del aprendizaje del alumno, se puede afirmar que con el desarrollo de este proyecto, los alumnos han conseguido afianzar y profundizar los conceptos adquiridos durante las clases lectivas de las asignaturas. Además, los resultados académicos obtenidos en la evaluación del POPBL en el curso 2014-2015, como se puede ver en la Gráfica 1, superan con creces las notas de los años anteriores a excepción de la asignatura de Gestión de Proyectos que tiene una nota inferior.



Gráfica 1: Histórico de resultados académicos del POPBL

Resulta oportuno destacar el aprendizaje por parte de los alumnos del método POPBL, basando el proceso de estudio en torno a una problemática real y tratando de dar respuesta al mismo. Así mismo, al tratarse de una situación real han lidiado constantemente con la empresa, descubriendo requisitos y necesidades de esta.

En igual forma, los grupos del proyecto han sido constituidos por alumnos de diferentes perfiles académicos. En consecuencia, se han creado sinergias aprovechando el conocimiento y experiencias de cada uno de los miembros, logrando así un aprendizaje colaborativo y una visión completa del problema.

4 Conclusiones

Hay algunos aspectos que son vitales para lograr el éxito del POPBL. Teniendo en cuenta el potencial impacto en el proyecto se pueden destacar los siguientes factores: el alcance y la coherencia de los objetivos, la organización en la supervisión de los entregables (con especial atención para evitar que sufra alteraciones), y la capacidad y disponibilidad de los profesores y empresa implicados en el proyecto.

El POPBL con una empresa permite el aprendizaje con una profundidad y realismo, esto no se puede lograr mediante la enseñanza tradicional. Aspectos tales como: la organización de las tareas de un grupo de trabajo, la comunicación directa con la empresa, la falta de respuestas en un plazo inmediato y la incertidumbre que ello conlleva o la presentación final donde se defiende el trabajo realizado delante del "cliente" final son nuevas experiencias para el alumno.

Así mismo, los resultados académicos obtenidos demuestran que los conceptos se han afianzado en la mayoría de las asignaturas de mejor manera en comparación con años anteriores. Este hecho denota que la problemática planteada ha sido adecuada para la culminación de los objetivos de cada asignatura. Sin embargo, en la asignatura concreta de Gestión de proyectos se han obtenido resultados académicos inferiores a la media de años anteriores. Considerando que la filosofía ágil es la acorde para desarrollar este tipo de proyectos, parece que los alumnos no han profundizado en los principios básicos del método Kanban, percibiéndose una mayor dedicación al trabajo técnico que al trabajo de gestión.

Finalmente, se puede considerar que la experiencia de incorporar la empresa en el POPBL puede ser un escenario idóneo para el inicio de Trabajos Fin de Master.

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Participation of an Industrial Holding in the Semester Project: a Case Study

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Abstract

This POPBL (Problem Oriented Project Based Learning) refers to a plastic injection company which supplies several assembly plants, all belonging to the same industrial holding. At the present, all companies work independently with a local perspective, developing a supplier - client relationship among them. In this context, both the lead time and the cost of stocks are high. During this semester project students have to analyze the origin of these problems and propose a solution from a global perspective, i.e., from a centralized management. This paper describes the operational work in used, summarizes the results obtained and collects the assessments of the people from the company, students and teachers involved in this project.

Keywords: Problem Oriented Project Based Learning; industrial management engineering.

Participación de un Grupo de Empresas Industriales en el Proyecto de Semestre: Estudio de un Caso

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Resumen

Este POPBL (Problem Oriented Project Based Learning) se centra en una empresa de inyección de plástico proveedora de varias plantas de montaje, todas pertenecientes al mismo grupo industrial. En la actualidad, se trabaja de manera independiente y con una visión local estableciéndose una relación cliente proveedor entre ellas. En este escenario, tanto el periodo de maduración logístico como los costes de stocks son elevados. En el proyecto de semestre los alumnos deben analizar la procedencia de estos problemas y plantear una solución con perspectiva global, es decir, con una gestión centralizada. El presente trabajo describe la operativa llevada a cabo, resume los resultados obtenidos y recoge la valoración por parte de las empresas, alumnado y profesorado que ha tomado parte en este proyecto.

Palabras clave: Problem Oriented Project Based Learning; ingeniería en organización industrial.

1 Introducción

Este POPBL (Problem Oriented Project Based Learning) (Lehmann, Christensen, Du, & Thrane, 2008; Markham, 2003) se desarrolla en el primer semestre del Máster Universitario en Innovación Empresarial y Dirección de Proyectos de Mondragon Unibertsitatea en el que se trabajan aspectos relacionados con la organización industrial. En este contexto, este trabajo tiene dos objetivos. En primer lugar, el mostrar un ejemplo de proyecto en ingeniería en organización industrial. En segundo lugar, partiendo de que el aprendizaje basado en proyectos orientado a los problemas de una empresa concreta aporta beneficios a los estudiantes, profesores y empresas (Chandrasekaran, Stojcevski, Littlefair, & Joordens, 2013; Chandrasekaran, Littlefair, Joordens, & Stojcevski, 2014), recoger indicaciones que puedan servir a esta u otra titulación.

2 Descripción del Proyecto de Semestre

2.1 Planteamiento del Problema

El POPBL se centra en una empresa de inyección de plástico proveedora de varias plantas de montaje, todas pertenecientes al mismo grupo industrial. En la actualidad, cada planta trabaja de manera independiente y con una visión local, estableciéndose una relación cliente proveedor entre ellas. En este escenario, tanto el periodo de maduración logístico como los costes de stocks son elevados. En el proyecto de semestre los alumnos deben analizar la procedencia de estos problemas y plantear una solución con perspectiva global, es decir, a través de una gestión centralizada. Con el fin de analizar realidades distintas, se han escogido tres talleres cuyas problemáticas y clientes son diferentes. Cada grupo de trabajo se centra en uno de los talleres y en la relación entre éste y la planta de inyección. La Figura representa la cadena de suministro a analizar.

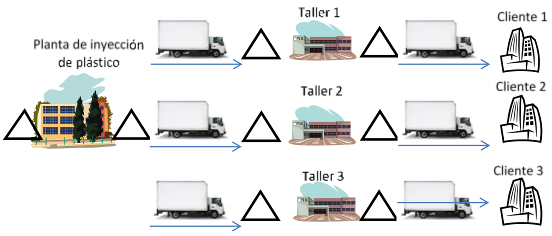

Figura 1: Representación de la cadena de suministro del grupo industrial

En lo que a las asignaturas se refiere, son cinco las asignaturas que participan en el proyecto: estadística, ingeniería de producción, operaciones para directivos, contabilidad y gestión de proyectos, esta última con un tratamiento especial, tal y como se observa en el punto 2.2 de este artículo. A continuación, la Tabla detalla los objetivos del resto de asignaturas:

Tabla 1: Objetivos por asignatura

Asignatura	Objetivos parciales
Estadística avanzada para la empresa	Analizar la demanda del cliente mediante una serie temporal. Analizar la tendencia de la serie y realizar predicciones.
Operaciones para directivos	Realizar un diagnóstico de la situación inicial respecto a la gestión de stocks y envíos en los distintos eslabones de la cadena de suministro.
	Proponer una cadena de suministro más eficiente que atienda a las condiciones establecidas por el cliente final.
	En la nueva propuesta, definir la planificación de la producción, la gestión de stocks y las necesidades de almacenaje en la planta de inyección.
Ingeniería de producción	Dibujar el Value Stream Mapping (Rother & Shook, 2003) del flujo de materiales y de información tanto de la situación inicial como de la nueva propuesta.
Contabilidad y finanzas para directivos	Evaluar la eficiencia de la situación mejorada en términos económicos.

2.2 Gestión del POPBL a través del Contenido de la Asignatura Gestión de Proyectos

La gestión del POPBL se realiza mediante una metodología analizada en la asignatura Gestión de Proyectos. En concreto, el objetivo fundamental es realizar una correcta gestión del proyecto según la metodología Kanban (Kniberg & Skarin, 2010; Pries & Quigley, 2010). Este método ágil se centra en maximizar el flujo de tareas, para lo que resulta clave limitar el trabajo en curso, que conlleva realizar el trabajo más rápido. Ello conduce a una mejora de productividad y plazos. La herramienta en la que se centra esta metodología, es el tablero Kanban (Figura 2) cuya finalidad es conocer cuál es la situación actualizada de cada una de las tareas.

Figura 2: Panel Kanban

2.3 Duración, Hitos y Entregables

En lo que a la duración se refiere este proyecto se realiza durante tres semanas consecutivas y con dedicación completa. Una vez se han impartido todas las horas lectivas, los alumnos dedican la totalidad de su tiempo al proyecto. Cara a comprender el desarrollo del proyecto, La Figura 3 muestra la calendarización del mismo.

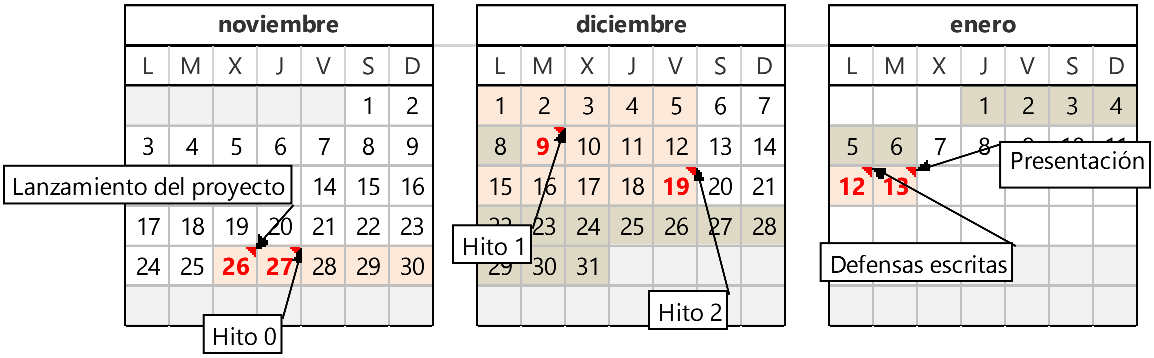

Figura 3: Planificación del POPBL

Tal y como se observa, además del lanzamiento inicial y la presentación y defensas finales, existen tres hitos intermedios programados. En el primero, el grupo establece la sistemática de gestión del proyecto; en el segundo, presenta un diagnóstico de la situación inicial; y en el último, define el nuevo planteamiento y las acciones a tomar para su ejecución. Cabe destacar que en cada uno de los hitos el grupo recibe una evaluación por parte del profesorado.

2.4 Evaluación del Proyecto

En la evaluación del proyecto se tienen en cuenta tanto la memoria final entregada como la defensa del proyecto. En concreto, la memoria supone el 60% de la nota mientras que la defensa supone el 40% restante.

2.5 Creación de Equipos de Proyecto

En alumnado del máster está compuesto por personas de distintos perfiles. En primer lugar, proceden de titulaciones distintas. La mayoría son ingenieros de distintas especialidades (organización, mecánica, diseño, electrónica e informática), sin embargo, hay personas procedentes de arquitectura. En segundo lugar, su experiencia profesional es distinta, hay personas con experiencia laboral previa. Por último, también hay alumnos extranjeros en el máster, participantes de programas de movilidad.

Desde el grupo de profesores no se han especificado criterios obligatorios en la creación de grupos, no obstante sí se ha recomendado la creación de equipos heterogéneos, teniendo en cuenta los criterios mencionados.

2.6 Soporte de los Tutores y Expertos

Cada uno de los equipos cuenta con un tutor y varios expertos. El tutor es la persona que asesora al grupo en el desarrollo del proyecto y además, da el feedback de cada uno de los hitos. Los expertos son los profesores de las asignaturas. Su labor es dar soporte a las dudas técnicas. Cara a impulsar la autonomía del grupo, el soporte de los expertos al grupo está limitado: el total de horas disponibles por grupo para hacer consultas a cada experto es de dos horas que se pueden distribuir como mucho en tres reuniones.

2.7 Comunicación entre los Distintos Participantes

La comunicación entre profesores y alumnos se realiza mediante los tutores. En lo que a la comunicación con las distintas empresas se refiere los canales han sido distintos. Por un lado, los alumnos han tenido contacto directo con los responsables de los talleres; todos han tenido contacto telefónico y por correo y en algunos casos han organizado visitas al taller. Por otro lado, el contacto con la planta inyectora se ha realizado a través de una profesora del máster. Además de visitar la planta inyectora al comienzo del proyecto, cada semana se han recopilado las preguntas de los alumnos y se han enviado a la empresa. Los tiempos de respuesta de las empresas han sido distintos; en algunos casos, la información ha llegado de manera inmediata, sin embargo, en otros las respuestas han tardado varios días.

3 Resultados Obtenidos

Dentro del análisis de los resultados se han analizado dos aspectos distintos. Por un lado, se han comparado los resultados académicos obtenidos en el proyecto. Por otro lado, se ha recogido la valoración de los distintos participantes en el POPBL (alumnado, profesorado y personas de empresa) a través de distintas encuestas.

3.1 Resultados Académicos

A la hora de valorar la experiencia de este año, un aspecto a considerar es los resultados académicos obtenidos por los alumnos. El Gráfico 1 recoge las notas medias obtenidas en las distintas asignaturas en los últimos cuatro cursos. Aclarar que los años anteriores los POPBL realizados no han estado unidos a una o varias empresas.

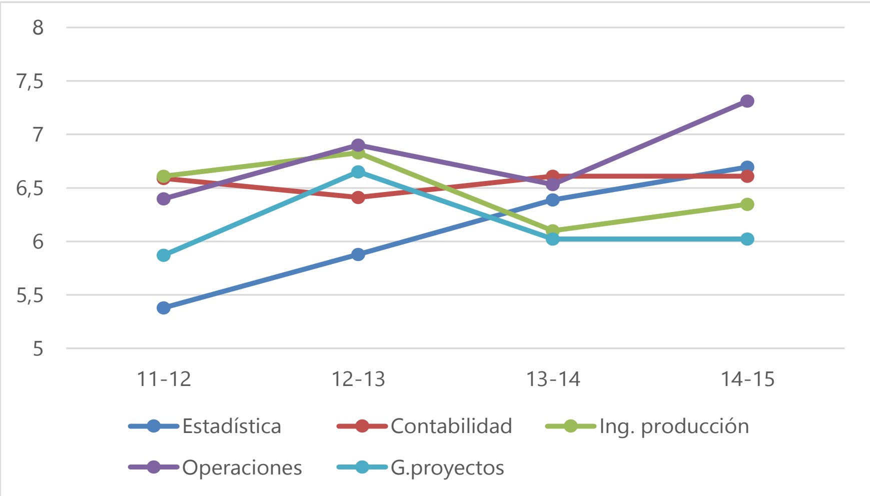

Gráfico 1: Notas medias obtenidas en el POBL en los últimos años

Tal y como se observa, los resultados obtenidos son mejores en Ingeniería de Producción, Estadística y sobre todo en Dirección de Operaciones. En el caso de Contabilidad y Gestión de Proyectos las notas medias obtenidas coinciden con las del año anterior. En general, se puede decir que los resultados académicos son parecidos a los obtenidos en otros cursos.

3.2 Resultados de las Encuestas

Se han preparado distintas encuestas con el objetivo de conocer la opinión del alumnado, profesorado y empresa. En los casos del profesorado y alumnado las preguntas han respondido a las mismas cuestiones. En el caso de la empresa, algunas de las cuestiones han sido distintas.

La Tabla 2 recoge los resultados de las encuestas al alumnado y profesorado. Se observa que existen similitudes y diferencias entre profesores y alumnos. En cuento a las similitudes, se observa que coinciden en que tanto la metodología POPBL como el trabajo en equipo aportan aspectos positivos. Además, todos los profesores y el 68% de los alumnos repetirían la experiencia de integrar a la empresa en el POPBL, aspecto que sin duda refuerza esta opinión. Además, alumnos y profesores coinciden que han existido problemas de comunicación entre el profesorado y el alumnado y sobre todo, entre el alumnado y las empresas. En cuanto a las diferencias, la manera de crear los equipos de trabajo y la forma de evaluar el proyecto son aspectos en los que alumnos y profesores no coindicen. Algunos alumnos consideran que los profesores debieran tener más participación en la creación de equipos, no sólo dando indicaciones sino marcando reglas. En cuanto a la evaluación, los comentarios de los alumnos hacen referencia a dos aspectos, a la corta duración de las defensas y al alto peso que la defensa tiene en la nota final (40%). Por el contrario, el profesorado está de acuerdo con las decisiones tomadas en estos dos aspectos.

Tabla 2: Resultados de las encuestas al alumnado y profesorado

Preguntas	Respuestas alumnado	Respuestas profesorado
La metodología POPBL, basada en problemas y proyectos es apta para la asimilación de contenidos técnicos.	Media obtenida: 3.67/5	Media obtenida: 5/5
El trabajo en equipo aporta aspectos positivos respecto al trabajo individual.	Media obtenida: 4.16/5	Media obtenida: 4.75/5
La forma de construir equipos de trabajo me parece adecuada.	Media obtenida: 2.53/5	Media obtenida: 4.25/5
La comunicación con la empresa	0% - Ha sido suficiente y ha llegado a tiempo 11% - Ha llegado a tiempo pero no ha sido suficiente 0% - No ha llegado a tiempo pero ha sido suficiente 89% - No ha sido suficiente y no ha llegado a tiempo	25% - Ha llegado a tiempo pero no ha sido suficiente 25% - No ha llegado a tiempo pero ha sido suficiente 50% - No ha sido suficiente y no ha llegado a tiempo
La comunicación entre el alumnado y el profesorado	47% - Ha sido suficiente y ha llegado a tiempo 26% - Ha llegado a tiempo pero no ha sido suficiente 5% - No ha llegado a tiempo pero ha sido suficiente 21% - No ha sido suficiente y no ha llegado a tiempo	50% - Ha llegado a tiempo pero no ha sido suficiente 50% - No ha llegado a tiempo pero ha sido suficiente
El sistema de evaluación (60% entregables, 40% defensa) me parece correcto.	Media obtenida: 2.42/5	Media obtenida: 4.5/5
Tu dedicación personal al proyecto en horas semanales ha sido:	5% - Inferior a 25 horas 5% - Entre 25 y 40 horas 79% - Entre 40 y 50 horas 11% - Más de 50 horas	No se pregunta
¿Repetirías el proyecto del primer semestre con empresa?	68% - Sí. 32% - No.	100% - Sí
La nota global que le doy al proyecto es la siguiente:	Media obtenida: 2.79/5	Media obtenida: 3.75/5

En el caso de la empresa, han respondido al cuestionario el responsable industrial del grupo y el director de la planta industrial. La Tabla 3 resume los resultados obtenidos.

En líneas generales, los participantes de la empresa están satisfechos con el trabajo realizado por los alumnos y con cómo se ha llevado a cabo el proyecto. Un aspecto positivo ha sido la corta duración del proyecto, el tener resultado en prácticamente dos meses ha sido un aspecto destacado. Sin embargo, también son conscientes que este es el motivo por el cual han existido factores que no se han trabajado. Respecto a la comunicación con los alumnos, las empresas son conscientes de que han existido problemas, pero no los consideran importantes.

Tabla 3. Respuestas de las personas de empresa

Preguntas	Respuestas empresa
Los resultados esperados han sido positivos y son útiles para la empresa	Media obtenida: 3.5/5
Los conocimientos previos al proyecto adquiridos por los alumnos en el máster son suficientes	Media obtenida: 4/5
El tiempo dedicado al proyecto me parece adecuado (preparación, visita y presentación final)	Media obtenida: 4.5/5
La duración del proyecto es acertada	Media obtenida: 4.5/5
La comunicación entre los participantes del proyecto se ha organizado correctamente (profesor interlocutor e interlocutores por grupo)	Media obtenida: 4.5/5
La comunicación entre alumnos y empresa	50% - Ha sido suficiente y se ha realizado a tiempo 50% - Se ha realizado a tiempo pero no ha sido suficiente
¿Has tenido experiencias anteriores en proyectos de semestre?	50% - Sí. 50% - No.
¿Repetirías el proyecto del primer semestre con empresa?	100% - Sí.
La nota global que le doy al proyecto es la siguiente:	Media obtenida: 4/5

4 Conclusiones

En primer lugar, parece que la metodología es apropiada ya que además de que los participantes la consideran apropiada, se observa que los resultados académicos y los resultados presentados a la empresa son buenos. Se puede decir que el problema planteado y los contenidos trabajados en el proyecto han sido apropiados para la titulación. No obstante, las valoraciones globales son muy distintas: las empresas y profesores muestran una satisfacción alta, no así los alumnos, donde existen diferencias.

En segundo lugar, también se concluye que algunos aspectos operativos han fallado. Parece que aunque la idea de dividir un problema global en grupos distintos es buena, la corta duración del proyecto ha impedido que el desarrollo fuera total. O dicho de otra manera, el tamaño del problema y el número de interlocutores era excesivo para una duración tan corta. Se observan dos aspectos clave. Por un lado, el día a día de las empresas hacen que la respuesta a los alumnos no sea inmediata y esto entorpece el avance del proyecto. Por otro lado, si los alumnos se equivocan en las preguntas o en los planteamientos disponen de poco tiempo de reacción.

Se concluye que este proyecto hubiera sido más exitoso si se hubiera realizado a lo largo del semestre, en paralelo a las clases lectivas y con unas pautas de comunicación cerradas.

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Construction Karts ¼ Mile, An Interdisciplinary Project Engineering and Design

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Abstract

This paper introduces an experience of interdisciplinary work between students of mechanical engineering and industrial design. The joint work allowed the design and construction of ¼ mile karts. The project was motivated by the growing automotive sector in Colombia and interest in the subject of young people. The project was developed in two stages using the methodology of 'co-design', as well as different strategies for following the student learning. The evaluation takes into account observations of teachers in both disciplines, and impressions of students that carry out the projects, students of related careers and competition pilots. Among highlighted results are the improving of professional commitment, chance to face an actual problem of Colombian Industry, and strengthening of teamwork skills. As a conclusion, students recognize that the project generated commitment, effort, responsibility and dedication, and improved their capability for valuing the ideas of others.

Keywords: interdisciplinary work, methodology of 'co-design', ¼ mile karts

La Construcción de Karts de ¼ de Milla, Un Proyecto Interdisciplinario de Ingeniería y Diseño

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Resumen

El escrito es una experiencia de trabajo interdisciplinario entre estudiantes de ingeniería mecánica y estudiantes de diseño industrial. El trabajo conjunto dio como resultado el diseño y construcción de un karts de ¼ de milla. El proyecto fue motivado por el crecimiento de sector automotriz en Colombia y la receptibilidad de los jóvenes por la temática. El proyecto se desarrolló en dos etapas utilizando la metodología de 'co diseño', así como, diferentes estrategias para el seguimiento del aprendizaje en los estudiantes. La evaluación involucró a docentes de las dos disciplinas, los mismos estudiantes del proyecto, a estudiantes de carreras afines y a pilotos de competencia. Dentro de los resultados se destaca la confrontación con un problema de la realidad industrial del país, el compromiso profesional y el trabajo en equipo. A manera de conclusión, la voz del estudiante reconoce que el proyecto generó compromiso, esfuerzo, responsabilidad y dedicación, como también aprender a valorar las ideas de los otros.

Palabras Claves: Trabajo interdisciplinario, diseño colaborativo, Carros de ¼ milla

1 Introducción

La experiencia interdisciplinaria que se presenta, pone de manifiesto el trabajo conjunto entre la Universidad Santo Tomas (USTA) y la Universidad Pedagógica y Tecnológica de Colombia (UPTC), con la colaboración de los aprendices técnicos del Servicio Nacional de Aprendizaje (SENA) y pilotos invitados. El proyecto formativo planteado se denominó: Diseño de un vehículo para carreras de ¼ de milla "Triciclo Motorizado". La intensión de la propuesta de trabajo buscó dos propósitos: explorar el trabajo interdisciplinario entre universidades e implementar una estrategia activa donde los estudiantes construyeran su conocimiento y potencializaran sus competencias profesionales, con el acompañamiento del docente. Sumado a lo anterior, desde el punto de vista técnico, tecnológico y en general de Ingeniería y Diseño, se buscó desarrollar los contenidos de las asignaturas: Ingeniería del Automóvil, que estudia los principios de ingeniería aplicados al vehículo, utilizando las herramientas y estrategias presentes en un ambiente real de trabajo; y la asignatura Diseño 4, funciones de la forma, que estudia y analiza la relación existente entre los componentes funcionales y formales de cualquier objeto de diseño. A continuación se desglosará la experiencia de aprendizaje en cuanto al ejercicio interdisciplinario, la estrategia activa, el seguimiento y evaluación al estudiante, los resultados de aprendizaje y la experiencia de vida que se construyó alrededor del diseño y fabricación de los karts de ¼ de milla.

2 La Interdisciplinariedad

Cuando se habla de la interdisciplinariedad como una forma de integración del conocimiento, se entiende como la interacción existente entre dos o más disciplinas:

> Puede ir de la simple comunicación de ideas hasta la integración mutua de conceptos directores, de la epistemología, de la terminología, de la metodología, de los procesos, de los datos y la organización de la investigación y de la enseñanza correspondiente. Un grupo interdisciplinario se compone de personas que han recibido una formación en diferentes campos del conocimiento (disciplinar) teniendo cada uno conceptos, métodos, datos y términos propios. (Apostel et al., 1972, p. 23-24).

Bajo este concepto de interacción, especialmente en cuanto metodología y procesos, se encontró que la Ingeniería y el Diseño son ciencias que involucran una enorme funcionalidad del automóvil, por estas razones la construcción de un vehículo motorizado para ¼ de milla aplicado a la vida productiva fue el germen creativo para desarrollar una comunicación de ideas, de contenidos programáticos de las asignaturas asociadas y lograr un acercamiento entre dos instituciones universitarias con características particulares: el carácter privado de la USTA y el carácter público de la UPTC y sus distanciamientos geográficos.

De esta forma, se inicia un acercamiento entre estudiantes y docentes de Ingeniería Mecánica de la Universidad Santo Tomas (USTA) y los estudiantes de Diseño Industrial de la Universidad Pedagógica y Tecnológica de Colombia (UPTC). En dicho acercamiento, y observada la naturaleza del proyecto, se consideró el pretexto perfecto para integrar enseñanzas y aprendizajes de las dos disciplinas. Desde la ingeniería mecánica se dio el soporte técnico al proyecto y desde el diseño industrial el soporte formal y ergonómico. Una vez, entradas en acción, los docentes de las dos disciplinas observan que los vehículos dedicados a la competencia de cuarto de milla son más flexible en su diseño, comparados con vehículos de mayor exigencia como los de fórmula uno, característica que fue aprovechada para incluirla como estrategia metodológica en las asignaturas, motivo por el cual, el tema de proyecto se vuelve común para estas. La interdisciplinaridad buscó concertar la asignación de responsabilidades, compartir el conocimiento de las profesiones para tomar decisiones con más propiedad en el desarrollo del vehículo, valorar el trabajo de los compañeros y la necesidad de trabajar en equipo para dar soluciones optimas al problema complejo que se les había planteado.

3 El Proyecto

3.1 La Motivación

El plan de gobierno para la presente vigencia en Colombia, ha seleccionado algunos sectores para estimular el crecimiento del país, uno de estos sectores es el de autopartes y son las instituciones de educación superior las llamadas a ejecutar proyectos que apoyen este desarrollo industrial y económico. Con base en lo anterior, las universidades vinculadas al proyecto, coincidieron en que la temática era pertinente por su aplicación real en el sector industrial automotriz y carrocero; el desarrollo coherente con los contenidos programáticos de las asignaturas base y su receptibilidad en los jóvenes estudiantes y la comunidad educativa, logrando potencializar su motivación por el proyecto. El grupo meta de estudiantes que participaron en el diseño y construcción del Karts, estuvo integrado por un total de 39 jóvenes, de los cuales ocho estudiantes hombres pertenecían al programa de Ingeniería Mecánica y 31 estudiantes al programa de Diseño Industrial, dentro de estos últimos, 14 fueron mujeres; sus edades oscilan entre los 17 a 20 años de edad y conformaron equipos de trabajo (de 3 a 4 estudiantes en promedio) de acuerdo a sus afinidades para el abordaje del proyecto.

3.2 El Desarrollo del Proyecto

Para la realización del proyecto se utilizó el "Co-diseño", entendido en palabras de Huertas (2013), como el hecho "de que la creatividad de los diseñadores se une a la de personas que tienen otros perfiles y trabajan juntas en el proceso de elaboración del diseño". El co-diseño también se relaciona con el "diseño Colaborativo", que busca aplicar la creatividad colectiva a través de todo el proceso de diseño, bajo un objetivo general que guíe al equipo de trabajo, permitiendo trabajar en paralelo sobre un mismo proyecto. Este diseño colaborativo contempla la participación de las dos partes implicadas en el diseño: el cliente y el diseñador; entendiendo que para este tipo de proyecto académico que se describe, tanto los estudiantes de ingeniería como estudiantes de diseño, toman su rol de cliente y diseñador al mismo tiempo. De acuerdo a lo expuesto por Sánchez (2013), "cada fase del proceso de diseño tiene que ser valorada por el cliente antes de tomar la decisión, usando parámetros adecuados y suficientes (p.7)"; para tal efecto, presenta cuatro aspectos metodológicos en el proceso de diseño colaborativo.

El primero corresponde a "despiezar el proceso en tareas, y evaluar cada una de ellas según el tiempo necesario para completarla", en este sentido, se determinó con el equipo de trabajo un cronograma que desglosó fases y actividades como: la fase de sensibilización del tema, donde se socializó las experiencias previas del equipo humano; la fase de investigación en la que se indagó sobre el tema, integrando varios tópicos: deportes de motor, historia del automóvil, componentes de un automóvil, concepto de aerodinámica, perfil del piloto y listado previo de requerimientos, entre otros; la fase de acercamiento a la problemática de diseño, que contempló el primer encuentro con el cliente, entrevista con los pilotos de carrera y expertos en el tema; la fase de consolidación de requerimientos de diseño, donde se discutió entre las disciplinas los requerimientos a tener en cuenta para el diseño del karts; la fase de desarrollo de concepto y bocetación, en la cual se materializó los requerimientos para llegar a la solución del problema; y finalmente, la Fase de ejecución del proyecto, donde se desarrollaron los cálculos, los modelos a escala y la construcción del prototipo.

El segundo aspecto metodológico del diseño colaborativo corresponde a "encontrar una unidad que permita poner en relación unas tareas con otras para fijar su peso relativo dentro del conjunto del proceso", desde esta perspectiva el ejercicio interdisciplinario del diseño de karts, dividió en dos unidades el proyecto: Estudiantes dedicadas al diseño de la forma exterior y al análisis del habitáculo del piloto (diseño de carrocería) y estudiantes dedicados al diseño de la estructura, suspensión, sistema de frenos, cálculo, selección del motor y del sistema de transmisión de potencia (diseño del chasis). Para el desarrollo de estas dos unidades, el trabajo de todo el equipo se dividió, a su vez, en dos etapas: la 'etapa A', partió de los requerimientos entregados: "*Diseñar un triciclo motorizado adaptando a un sistema de potencia con cilindrada inferior a 150 cc, cumpliendo condicionantes de diseño, fabricación de las autopartes diseñadas, ensamble del triciclo motorizado, elaboración de las memorias soporte del proyecto y socialización de la experiencia ante estudiantes y docentes invitados*". Bajo estos primeros requerimientos el grupo de Ingeniería apoyados en el liderazgo del estudiante Simón Ávila, realizan el diseño del chasis, y el grupo de diseñadores desarrollan dos propuestas de carrocerías basadas en este, ver figura 1. Por cuestiones de tiempo, las carrocerías no fueron ensambladas al chasis, y este debió ser ajustado en algunos componentes mecánicos; sin embargo, esta etapa, permitió la exploración del trabajo interdisciplinario, la corrección de modelos y los lazos de familiaridad para para iniciar la 'etapa B del proyecto'.

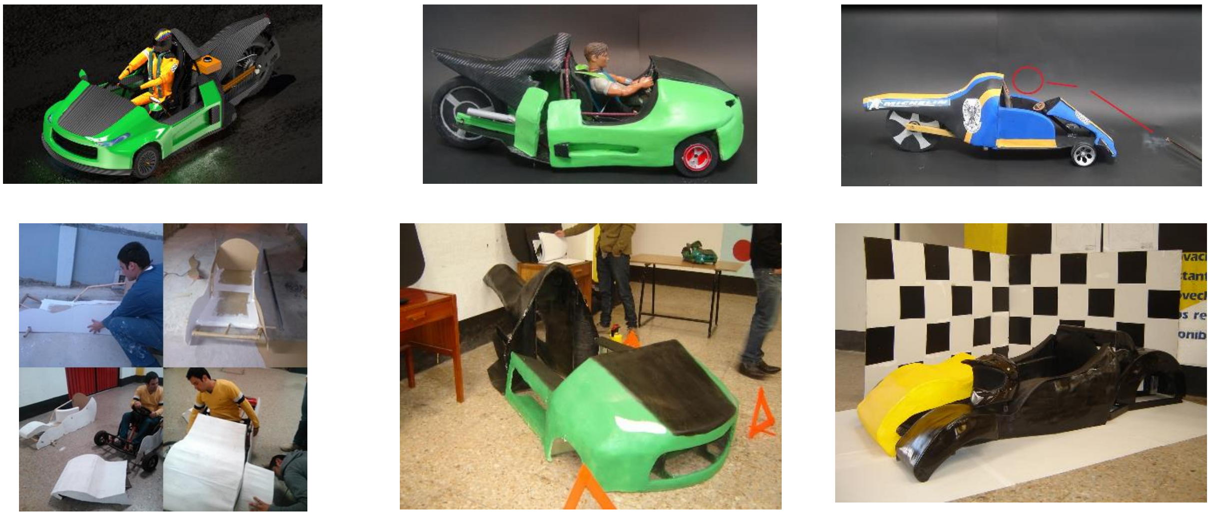

Figura 1: Resultados Etapa A: Renderizados, modelos a escalas, construcción de la carrocería y modelos finales, estudiantes de Diseño Industrial Uptc.

La etapa B, inicia con la evaluación de los resultados y su retroalimentación para la nueva experiencia de trabajo, de acuerdo al diseño colaborativo es importante documentar el trabajo realizado para que el proceso de diseño sea abierto y permita la incorporación de manera fácil e inmediata de nuevos diseñadores, es así, como esta etapa B es conformada por nuevos estudiantes, quienes se motivan por completar el reto.

Los estudiantes de la etapa A, juegan el rol de asesores de sus compañeros. Entre todo el grupo de ingeniería y diseño concertan los requerimientos para la mejora del vehículo motorizado. Para esta etapa el grupo de ingeniería se encarga de poner a punto el chasis, mientras tanto el grupo de diseño realiza bocetos y maquetas de alternativas de carrocerías, para cuando está a punto el chasis, se inicia la adaptación de la carrocería, de esta forma se logran seis carrocerías diferentes y un chasis con tracción trasera, un eje basculante que permite absorber las irregularidades del terreno, un chasis tubular que presenta doble cuna para el alojamiento del motor y doble cuna para la ubicación del piloto, ver figura 2. En la dirección se identifica la aplicación del mecanismo cuadrilátero articulado, la suspensión trasera es del tipo rueda tirada con bieletas sencillas y la delantera de rueda empujada, con transmisión tipo.

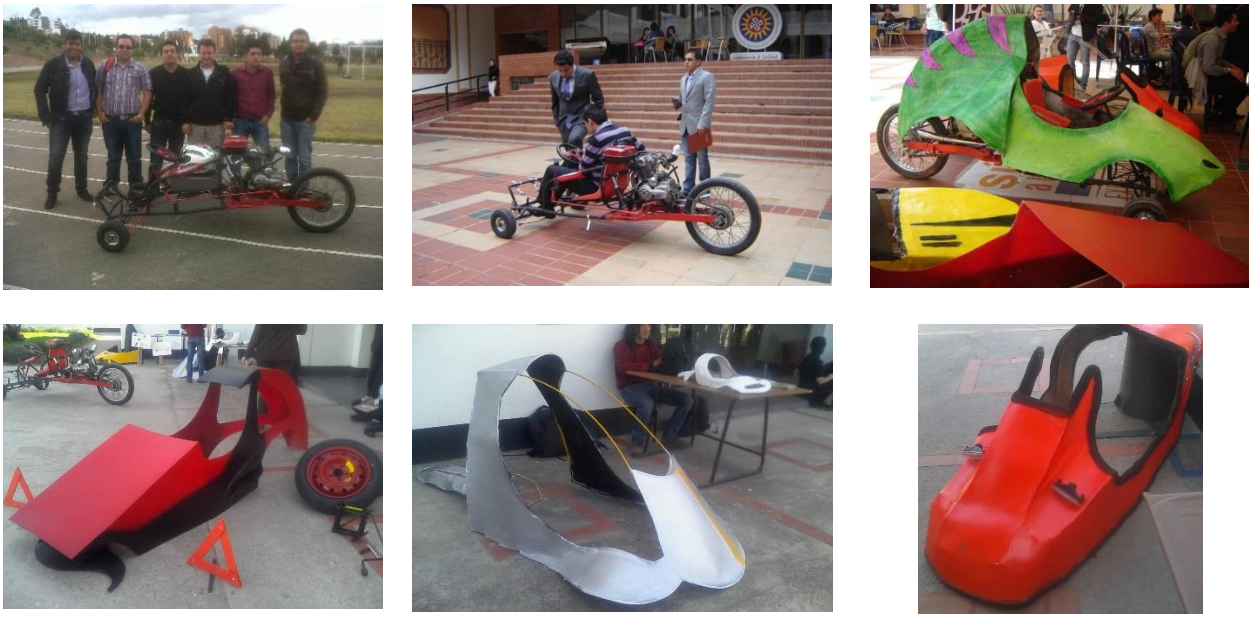

Figura 2: Equipo de Ingeniería Mecánica de la Usta, Chasis a punto, diferentes carrocerías.

De acuerdo con Sánchez (2013:7), el tercer aspecto metodológico del diseño colaborativo enfatiza en incorporar los parámetros que definen la cantidad de conocimientos necesarios para desarrollar cada tarea; para el diseño del kart, los diseñadores exploran sus conocimientos en cuanto al desarrollo de proceso abstracción de la formal, su capacidad para comprender el método de diseño y su aplicación en la solución a un problema de diseño, su capacidad para aplicar procedimientos, técnicas e instrumentos que permitan recolectar, analizar y procesar información, su capacidad para analizar el usuario, su contexto y actividad que lo conduzca a determinar requerimientos de uso, componentes técnicos, requerimientos funcionales, componentes formales, requerimientos de tipo estético, simbólico y semiótico para la configuración de la forma. Por su parte el equipo de ingenieros abordan sus conocimientos sobre ingeniería del automóvil, sus orígenes, nombres asignados a través de la historia, identificación moderna, normatividad internacional, análisis de la clasificación de los motores de combustión interna, ciclos termodinámicos del comportamiento dependiendo del principio de funcionamiento y el combustible utilizado, sistemas generales del vehículo, sus componentes, funcionalidad y diseño, aplicación de la ergonomía y seguridad pasiva, análisis del control electrónico del motor, sus entradas, procesamiento y salidas, protocolos de comunicación, herramientas de diagnóstico y reparación de los sistemas integrados en el vehículo

Para finalizar, el cuarto aspecto metodológico, corresponde a valorar de manera cualitativa que utilidad futura puede tener para el cliente adquirir dichos conocimientos; entre ellos se encuentran las reflexiones que hacen los estudiantes sobre la importancia del trabajo del otro profesional para cumplir el objetivo, ver figura 3.

"El trabajo en equipo y la articulación con la universidad Santo Tomas fue de gran aprendizaje, nos enseñó el modo de trabajar con un cliente, aportó gran conocimiento y seriedad a la hora de desarrollar el trabajo como aspectos para la vida profesional. El desarrollo de la carrocería tuvo compromiso, esfuerzo, responsabilidad, y dedicación para complacer al cliente; uno de los grandes objetivos del diseñador industrial.". Miguel Ángel Reyes

"nos introdujo a la utilización de metodología, pasos a seguir y responsabilidad de un proyecto, se utilizaron los conceptos de forma, función y la importancia a la hora de crear un producto, la coherencia entre formal y extra formal para que nuestro diseño sea objetivo". Michel Mahecha

"Parte de nuestra vida laborar es trabajo en equipo, saber valorar todas la ideas aportadas, se aprende a socializar y entender el trabajo de cada uno, aportando a la mejor idea de todas". Laura Sainea

Figura 3: Expresiones de los estudiantes sobre las experiencias

4 Seguimiento al proyecto

El seguimiento a los estudiantes se desarrolló de acuerdo con el cronograma de trabajo acordado, en el cual se incluían, sesiones de asesoría, entregas de informes de avance y momentos de socialización con la otra disciplina. En las sesiones de asesoría, cada docente tutor se reunía con sus estudiantes para acordar soluciones a los inconvenientes o responder las dudas que se presentaban en el desarrollo del proyecto. Para la entrega de informes de avances, tanto estudiantes de diseño como de ingeniería desarrollaban sus portafolios con el registro del proceso de diseño, la información recolectada sobre el tema, los cálculos del chasis, los bocetos de alternativas para la carrocería, sus procesos de fabricación y sus conclusiones sobre la experiencia de trabajo; estos informes de avance permitieron llevar el control por parte de los estudiantes y el docente sobre la trayectoria en el desarrollo del proyecto. Los momentos de socialización reunían todo el grupo de trabajo, para el despeje de dudas, la concertación de compromisos y la integración de los estudiantes, Ver Figura 4.

Figura 4: Momentos de socialización y evaluación

Otro elemento importante dentro del seguimiento al proyecto, fueron las reuniones de discusión entre docentes tutores y asesores, estos últimos eran un grupo de docentes externos a las asignaturas, cuya experiencia permitía complementar el trabajo interdisciplinario. Con los asesores se mantuvo una comunicación constante para debatir los adelantos del proyecto y visionar estrategias de crecimiento para garantizar el éxito del proceso de aprendizaje. Ver tabla 1, sobre los resultados de las estrategias de seguimiento.

Tabla 1: Resultados de las estrategias de seguimiento

Estrategia	Resultados y Evidencias
1. Cronograma de trabajo	Es un instrumento que planeó el ejercicio académico, en fases y actividades, duración por semanas, resultados esperados e indicadores de seguimiento, entre los que se contempló: presentaciones, informes, listados de asistencia, evidencias fotográficas, listado de requerimientos, libro de bocetos, modelos a escala, videos de pruebas y listas de chequeo.
2. Sesiones de asesoría	Son encuentros entre el docente tutor y los equipos de trabajo, en estas sesiones el docente registra en el diario de clase los avances sobre el trabajo de cada equipo, se desarrollan acuerdos y compromisos entre las partes para el desarrollo del ejercicio
3. Informes de Avance	Los informes de avance son documentos escritos en los que el equipo de trabajo registra la información recopilada durante el transcurso de desarrollo del proyecto, en ellos se evidencia la fase analítica de recolección de información, la fase creativa de búsqueda de solución al problema y la fase ejecutiva de construcción de la solución.
4. Encuentros de Socialización	Son espacios definidos desde el cronograma, para el encuentro entre las dos disciplinas, en los cuales se buscó la socialización del trabajo realizado por cada equipo de trabajo, su evidencia se recoge en actas de reunión, registro fotográfico, listado de asistencia.
5. Encuentros con expertos	Espacios en los que se invita a expertos (diseñadores, ingenieros, pilotos) para que retroalimente los resultados del proceso de diseño; sus aportes son tenidos en cuenta para el avance del proyecto, que se ve reflejado en la construcción de los modelos de carrocerías y mejoras del chasis.
6. Guías de Aprendizaje	En el caso de Ingeniería Mecánica, para garantizar la cobertura de los contenidos programáticos se desarrolló una guía sobre los diversos elementos y sistemas existentes en los vehículos (automóviles) actuales, así como su influencia en la respuesta dinámica. Los estudiantes paralelamente con el desarrollo del proyecto fueron desarrollando la guía y presentando informes sobre la misma.

Las estrategias de seguimiento presentadas en la tabla 1, permitieron a los docentes y estudiantes coordinar tiempos, ilustrar los alcances en cada fase del proyecto, mantener una comunicación continua entres todos los actores, determinar acciones, acuerdos y compromisos en relación con los avances de trabajo de cada equipo, mantener una inclusión permanente de la otra disciplina en las decisiones, escuchar nuevas voces que retroalimentaban la practica desde su experiencia y alcanzar el cumplimiento del contenido programático de las asignaturas vinculadas.

5 La evaluación

La evaluación involucró a los docentes, los equipos de trabajo, estudiantes de otros programas técnicos y algunos pilotos de carreras, y se desarrolló observando los conceptos y las habilidades relacionadas con los resultados de aprendizaje en: i) el diseño y componente técnico del chasis, ii) la evaluación de alternativas de carrocerías y iii) el ensamble de la carrocería al chasis. Para el caso de Ingeniería Mecánica, la evaluación se enfocó en verificar la competencia profesional de los estudiantes para calcular variables como peso, centro de gravedad, potencia del motor, relación de transmisión, suspensión, fuerza de frenado, transmisión de fuerzas al frenado, diseño de la estructura, análisis de esfuerzos de la estructura, selección del material comercial para la construcción de la misma, selección del tipo de suspensión, selección de llantas y diseño del sistema eléctrico requerido. En el caso de Diseño Industrial, la evaluación se centró en: la pertinencia de la información recopilada para comprender el contexto de la problemática de diseño: Historia del automóvil, deporte de motor, antecedente contextual, historia de la aerodinámica, soluciones existentes, entre otros; la eficacia en la descripción del modelo ergonómico, proceso (tareas y actividades del usuario), ser humano (aspecto fisiológico, psicológico y sociológico del usuario) y ambiente en el que se realiza la actividad; la correspondencia entre el desarrollo de las alternativas de diseño y los requerimientos planteados; el desarrollo de modelos a escala y pruebas de aerodinámica; la pertinencia del análisis morfológico, las cartas de producción, y los costos aproximados de la fabricación; finalmente el desarrollo de la exposición de la solución de diseño, el portafolio del proyecto, los planos técnicos de construcción, la presentación digital y el modelo funcional. Para las dos disciplinas fue importante evaluar el desempeño como equipo de trabajo, el rol en el equipo, el compromiso con el equipo, y la habilidad para concertar y evitar discrepancias.

6 Resultados de Aprendizaje

Dentro de los resultados de aprendizaje, se pueden enumerar los siguientes para el rol estudiante: Enfrentarse a un problema, que les permite confrontar la realidad industrial y productiva del país; desarrollar una actitud responsable ante los compromisos con otros profesionales; ser incluyente en su práctica de trabajo, escuchar la voz de otros profesionales que apoyan sus conocimientos; llevar su práctica académica a otras instancias fuera de su salón de clases y su propio ambiente universitario, mostrando lo mejor de sí, para el cumplimiento del trabajo en equipo y los objetivos de las asignaturas que integraron el desarrollo del proyecto. En cuanto al rol de docente, se aprendió a organizar el tiempo para un mejor seguimiento del aprendizaje en los estudiantes, a estar en un constante dialogo con sus pares, para coordinar objetivos, tareas, actividades que llevaran a feliz término las condiciones de trabajo para las dos profesiones y apoyar a los equipos de trabajo en los altibajos de su experiencia en el proyecto, Ver figura 5.

Figura 5: La satisfacción del deber cumplido

7 Conclusión

La temática del proyecto despierta en los jóvenes estudiantes el interés por lo desconocido, tomando con más seriedad su formación profesional, pues se enfrentan a un trabajo interdisciplinario, que exige poner en práctica los conocimientos adquiridos a lo largo de su vida estudiantil y confrontarlos con otros semejantes.

La metodología del diseño colaborativo, permite el desarrollo de un diseño más flexible, que se adaptó mejor a las condiciones de tiempo, recursos y distanciamientos geográficos entre los actores de este proyecto académico, permitió crear autonomías para decidir y concesos para llegar a acuerdos. Su proceso hizo incluyente a varios actores en diferentes momentos, siendo partes activas en el proceso y las tomas de decisiones.

El proyecto ofreció un desarrollo metodológico que permitió a los estudiantes construir su conocimiento a través de la práctica del mismo, usando como guía los contenidos programáticos de las asignaturas, las diferentes estrategias diseñadas para el seguimientos del mismo, lo que permitió fortalecer   sus competencias formativas en cuanto a: su capacidad de liderazgo e iniciativa y trabajo en equipo, su capacidad de motivar y conducir hacia metas comunes, para trabajar en forma autónoma, para la crítica y autocrítica; organizar y planificar el tiempo e innovar y desarrollar su pensamiento creativo

Se evidenció cómo el trabajo interinstitucional e interdisciplinar facilita el desarrollo de capacidades trasversales a través de la exigencia de responsabilidad para cumplir con los compromisos pactados, la coordinación de actividades interdisciplinarias, la búsqueda de estrategias para resolver los conflictos al interior de los equipos y la complementariedad entre campos como la ingeniería y el diseño, acercándose así a un ambiente de trabajo profesional.

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PBL in Systems Engineering Grades: a Bottom-Up Perspective.

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Abstract

Nowadays, academy faces different challenges related to development of students´ skills. Implementation of learning philosophies as PBL (Problem Based Learning) is an effort that usually initiates at university high-level support (Top-down), or from operational levels (bottom-up). This article describes the bottom-up implementation of the PBL philosophy at National University (UNA), Costa Rica. The specific implementation initiated in 2008 in the Systems Engineering courses. In this implementation, several technical and soft skills were integrated by considering close collaboration with industry. In this context, the students technically lead a software development project in a real company. Among other, the PBL implementation included different techniques such as awareness, self-learning, comparative analysis of theory and practice as well as formal and informal advice. In order to assess the impact of this implementation, we conducted a survey study with participation of actual and formal students as well as industry. Results suggest that an initiative of implementing the PBL from a lowest hierarchical level,, is perceived as a valuable experience for companies. Additionally, actual and former students feel that they have learned more and at the same time contribute with the country development. University-industry projects and the learning process allow students' empowering, provides feedback to improve curricula, allow a learning process by considering relation of students with an organization and finally, contribute with organizations' development.

Keywords: Strategy and Implementation of PBL; Education in Systems Engineering; University Industry Projects.

PBL en Carreras de Ingeniería de Sistemas: una Perspectiva *Bottom-Up*

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Abstract

La academia enfrenta cada día más retos relacionados con el desarrollo de competencias de los estudiantes. La implementación de filosofías de aprendizaje como el PBL (Problem Based Learning) representa un esfuerzo iniciado con apoyo de los niveles superiores en las universidades (Top-down), o desde niveles operativos (bottom-up). Este artículo describe la implementación de la filosofía PBL desde una perspectiva bottom-up, en la Universidad Nacional (UNA), Costa Rica. La implementación específica inició en 2008 en los cursos de Ingeniería de Sistemas. En esta implementación, varias habilidades técnicas y blandas fueron integradas considerando una estrecha colaboración con la industria. En este contexto, los estudiantes lideran técnicamente un proyecto de desarrollo de software en una empresa real. Entre otras cosas, la implementación de PBL incluyó diferentes técnicas tales como sensibilización, autocapacitación, análisis comparativos de la teoría y la práctica, así como asesorías formales e informales. Para medir el impacto de esta implementación, hemos conducido un estudio de encuesta con la participación de estudiantes, egresados y representantes de la industria. Los resultados del estudio sugieren que una iniciativa de implementación del PBL desde el nivel jerárquico más bajo, es percibida como una experiencia beneficiosa para las empresas. Adicionalmente, los estudiantes y egresados sienten que han aprendido más y al mismo tiempo, contribuyen al desarrollo del país. El desarrollo de los proyectos universidad–industria y el proceso de aprendizaje, empoderan a los estudiantes, retroalimentan las mejoras a los planes de estudio, facilitan el proceso de aprendizaje a través del contacto con una organización y contribuyen al desarrollo de las organizaciones.

Keywords: Estrategia e Implementación del PBL; Educación en Ingeniería de Sistemas; Proyectos Universidad industria .

1 Introducción

De forma intuitiva y sin principios pedagógicos aplicados de manera consiente, la cátedra de Ingeniería de Sistemas, conformada por profesores y estudiantes de los cursos de Ingeniería de Sistemas I,II y III de la Carrera de Ingeniería de Sistemas de la Universidad Nacional (UNA) de Costa Rica, desde el año 2006 renovaron radicalmente el proceso de enseñanza aprendizaje que tradicionalmente se venía utilizando, no solo con relación a las actividades desarrolladas dentro y fuera del aula, sino con la filosofía y cambio de esquemas mentales de los docentes.

Con una estructura innovadora y de la cual no se han ubicado en la literatura casos similares, los estudiantes desarrollan un software en una empresa real durante 3 semestres consecutivos. En el proceso deben aprobar los 3 cursos de manera independiente, cuentan con diferentes supervisores, incluso algunos miembros de los equipos de trabajo de estudiantes no son compañeros de clase y en otros casos el profesor que supervisa el proyecto no es su profesor de curso. Lo anterior genera una dinámica donde se requiere organización, confianza, ética, coordinación, procesos de comunicación y retroalimentación entre profesores, estudiantes y representantes de las empresas comparables con estándares de clase mundial.

A partir del 2009 y como resultado de un proyecto de investigación llevado a cabo en conjunto con la Universidad de Aalborg, el cuerpo docente estuvo en contacto con expertos de la filosofía base de esta universidad: el Aprendizaje Basado en Problemas, PBL por sus siglas en inglés (Problem Based Learning) y una de sus variantes como lo es el aprendizaje basado en problemas orientado a proyectos, POPBL por sus siglas en inglés Project Oriented Problem Based Learning. Las semejanzas de los principios del POPBL y las acciones semiestructuradas que se realizaban en la cátedra desde el 2006 con estas filosofías propiciaron el desarrollo de una propuesta y posterior implementación formal del POPBL en la UNA.

Este artículo muestra los resultados obtenidos hasta la fecha de esta implementación que formalmente inicio a principios del 2009. El trabajo se ha organizado iniciando en la sección 2 con un resumen del contexto bajo el cual se desarrolla este proceso de implementación, seguidamente en la sección 3 se describen los aspectos metodológicos como son las técnicas, herramientas, instrumentos, participantes, forma en que se recolectaron los datos y cómo se llevó a cabo el análisis de resultados. En la sección 4 se discuten los resultados y finalmente en la sección 5 se muestran las conclusiones y los trabajos futuros producto de este estudio.

2 Contexto de Desarrollo de la Implementación de POPBL en la UNA

2.1 Perfil del Profesional en Ingeniería de Sistemas en Costa Rica

Si bien los conocimientos y habilidades relacionados con aspectos técnicos son fundamentales en el desarrollo profesional, bajo la conceptualización de universidad pública, la UNA va más allá del ámbito meramente comercial, ya que propicia valores, ética, conciencia social como parte fundamental de su modelo pedagógico. (Universidad Nacional, 2005). Un estudio realizado entre 1995 y 1997 entre 36 empresas danesas y 269 compañías norteamericanas, Kolmos (2007) mostró que las demandas en características de sus empleados actuales y futuros van sobre esa línea, específicamente para Costa Rica varios estudios han determinado deficiencias no solo en la cantidad sino en la formación de profesionales en TI. (Pinto, 2009) (Mata, 2003) (Brenes, 2008).

Por ejemplo el informe del proyecto siglo XXI en su apartado de Recursos Humanos en informática, muestra la importancia algunos elementos a considerar para los formadores "… la industria costarricense de software plantea a las instituciones de educación superior desafíos como: enfoque a solución de problemas, alto énfasis en el idioma inglés, predisposición al trabajo en equipo, énfasis en administración de proyectos y logro de objetivos, cultura de la Calidad, orientación de programación objetos….." (Macaya, G.(comp), 2006)

Estas demandas evidencian un cambio en la forma en que las universidades deben de abordar el proceso de formación, dejando atrás enfoques tradicionales, e incorporando filosofías como el POPBL que si bien no son nuevas en el contexto internacional, son innovadoras para el ámbito costarricense y aún mas en Ingeniería de Sistema.

2.2 POPBL como Base para la Implementación

Formalmente el PBL nació para estudiantes de medicina en Mac Master Medical School of Canada y se ha extendido a través del mundo (Lehmann, 2008). La idea es que los estudiantes aprendan haciendo, lo que permite que se apropien de un problema, con el fin de que la necesidad de resolverlo estimule su aprendizaje. Una de las ventajas de PBL, es precisamente que a la hora de resolverlo, los datos no se presentan de manera estructurada ni completa y es ahí donde el estudiante es el que debe de consolidar la información, buscarla y tratar de resolver la situación. El estudiante está consciente que debe de aprender o por lo menos explorar algo para resolver esta situación, que para cada caso es única. (Tracey, 2008).

Se quiere entonces que el estudiante planifique la forma en que buscará la solución del problema o el tratamiento de la situación. Branda (2001) dice que el punto de partida para las necesidades de aprendizaje es precisamente el problema. Kolmos (2007) presenta las principales características del PBL, entre ellas la solución de Problemas complejos y poco estructurados que están frecuentemente asociados al mundo real y actúan como estímulo para el curso, currículo o programa, el aprendizaje está centrado en el estudiante, el instructor toma un rol de facilitador y otras que se ajustan al modelo implementado en la UNA.

Una de los principales cambios con respecto al proceso de aprendizaje es que el profesor se transforma en un facilitador. En el caso específico de la cátedra de sistemas de la UNA, el problema a solucionar es precisamente una solución de software para una empresa real, de aquí que se utilice un enfoque complementario denominado POPBL (Project Based Problem Based Learning) aprendizaje basado en problemas orientado a proyectos. (Lehmann, 2008)

La principal diferencia con el PBL es que en el POPBL existe una asignación o tarea de mayor duración, por ejemplo en los campos de la ingeniería los productos, son un diseño, un sistema, que debe de llevarse con el trabajo en equipo y produce un producto único en un determinado periodo. (Lehmann, 2008).

2.3 Metodología: Participantes, Instrumentos y Técnicas para Recolectar la Información, Análisis de Datos.

2.3.1 Participantes

La cátedra está conformada por profesores y estudiantes de los cursos Ingeniería de Sistemas I, II y III, estos se ubican a partir del tercer año de la carrera de Ingeniería de Sistemas. Los estudiantes tienen una edad promedio de 22 años y en su mayoría (70%) son del sexo masculino. Los estudiantes consultados corresponden a los que cursaron Ingeniería de Sistemas I y III en el I semestre del año 2011. Se obtuvieron respuestas de un total de 210 estudiantes: 118 de Ingeniería I y 92 de Ingeniería III.

Con base en las listas de clases se determinó que 487 estudiantes finalizaron el curso de Ingeniería de Sistemas III entre los años 2006 y 2011. . Fueron consultados también para considerar, entre otros aspectos, su percepción en el proceso de aprendizaje, tomando en cuenta, además, que la mayoría se encuentra laborando en áreas relacionadas con las TIC y su aporte enriquece aún más los resultados.

Tomando en cuenta que los estudiantes realizan proyectos en una empresa real, los representantes de estas compañías son participantes activos en el proceso de aprendizaje y colaboración. Con base en la información de los proyectos del 2007 a 2010, se calcula que existen de 10 a 15 proyectos de los cuales no se cuenta información.

Las 117 empresas participantes se clasificaron de acuerdo al Ministerio de Planificación de Costa Rica (MIDEPLAN) en microempresas (hasta 9 empleados) , pequeña (hasta 32 empleados), mediana (hasta 29 empleados) y grande(más de 30 empleados) . Las principales actividades económicas de estas empresas son servicios, educación y comercio.

Tabla 1: Población de Empresas participantes por clasificación MIDEPLAN

Clasificación	Cantidad	Porcentaje
Microempresa	9	8%
Mediana	29	25%
Pequeña	32	27%
Grande	47	40%
Total	117	100%

Fuente: Proyecto Análisis de impacto de proyectos desarrollados por los estudiantes de la Cátedra de Ingeniería de Sistemas de la UNA del 2006 al 2010

Los 7 profesores que imparten el curso son Ingenieros de Sistemas, todos se desempeñan en la industria de la Ingeniería de Sistemas con más de 10 años de experiencia profesional. 2 académicos de tiempo completo con más de 15 años de experiencia docente y 5 de tiempo parcial con un promedio de 5 años de experiencia docente.

2.3.2 Instrumentos y técnicas de recolección de datos

Para lograr la aplicación del POPBL se realizaron una serie de actividades y aplicación de técnicas en un ambiente colaborativo y de continuo aprendizaje tanto del cuerpo docente como de los estudiantes e involucrados por parte de las empresas. Como fue el caso de la colaboración, de la Universidad de Aalborg: resultando ser una guía con trayectoria y liderazgo en el tema de PBL (Camacho, 2010). Los profesores realizaron un análisis comparativo entre prácticas de la UNA, considerando los aspectos que de manera empírica se aplicaban en la UNA y los principios del POPBL (ver Tabla 2 Análisis comparativo POPBL- Prácticas de la Cátedra).

2.4 Sensibilización de académicos

La sensibilización de académicos se llevó a cabo a través de reuniones y talleres, donde se realizaron análisis retrospectivos, revisiones bibliográficas y exploración de los datos y los resultados. Se adoptó formal y voluntariamente, por los docentes, como valor fundamental la humildad profesional, el pensamiento independiente y crítico, solidaridad y trabajo en equipo entre otros que propician la consolidación de un ambiente colaborativo y de aprendizaje entre los profesores para continuar con el cambio.

Considerando que el cuerpo docente posee una escaza formación pedagógica, pero un espíritu autodidacta, la asesoría de expertos, la revisión bibliográfica, las sesiones de lecciones aprendidas no solo permiten realizar mejoras sino que empoderan y motivan a los profesores a continuar con el proceso de cambio. Profesores de tiempo parcial que laboran en otras organizaciones han demostrado su interés a través de estos años en busca de la excelencia.

2.5 Sensibilización de la Dirección de la escuela

Para impulsar el cambio se requirió la permanencia de los profesores, que ya han demostrado su compromiso, con experiencia en la forma de trabajo con los estudiantes y las empresas. Considerando que únicamente 2 profesores trabajan tiempo completo y de forma permanente para la UNA, se requería lograr la estabilidad laboral de los participantes, conocedores del enfoque metodológico utilizado, minimizar la curva de aprendizaje y promover un clima de confianza.

El apoyo por parte de la dirección de la escuela se ha concretado logrando el nombramiento de manera constante, aunque no continua, de los profesores participantes desde el 2009, a pesar de las limitaciones legales y presupuestarias que afrontan las universidades públicas en Costa Rica.

2.6 Análisis del impacto en el proceso de enseñanza aprendizaje en los involucrados

Para adquirir evidencias formales sobre las implicaciones de aprendizaje en los estudiantes, se llevó a cabo, entre 2010 y 2012, el proyecto de investigación (Sandoval, 2014). Se realizó este estudio con el objetivo, entre otros aspectos, de conocer sobre la percepción relacionada con el proceso de enseñanza aprendizaje de los estudiantes, egresados profesores y participantes de las empresas donde se desarrolló el proyecto.

Se seleccionaron muestras aleatorias de egresados, estudiantes activos y representantes de empresas. Para los egresados y empresas se seleccionó una muestra aleatoria del 50% de los participantes con información de correo electrónico o número telefónico.

2.7 Análisis de datos

Los datos fueron analizados, utilizando diferentes técnicas, para las preguntas cerradas de las encuestas se utilizaron análisis de frecuencias y promedios, para las preguntas abiertas se realizó un codificación selectiva de datos.

Se aplicó también la inducción analítica, donde los resultados y conclusiones se derivan de los datos principalmente de los elementos cualitativos como talleres y reuniones.

Tabla 2: Análisis comparativo POPBL- Prácticas de la Cátedra

Principios Aprendizaje Basado en Problemas orientado a proyectos (POPBL)	Elementos utilizados antes de la formalización de la propuesta.
El aprendizaje basado en una formulación de la problemática	La problemática a resolver es el desarrollo de una solución de software para una empresa
Procesos de aprendizaje sean dirigidos por los participantes,	El grupo de proyecto está formado por los estudiantes, aunque los profesores orientan el conocimiento teórico los estudiantes deben de buscar las soluciones
El aprendizaje basado en la experiencia	Los estudiantes han cursado materias de programación, bases de datos y otros donde han realizado proyectos. Además de otras materias donde han tenido contacto,
Aprendizaje basado en una actividad	La actividad principal para la aplicación del aprendizaje es el proyecto que se realiza durante los tres cursos de Ingeniería de Sistemas y donde el aprendizaje basado en problemas se orienta a los proyectos.
Interdisciplinariedad	Los proyectos de tecnología de información, específicamente el desarrollo de sistemas tiene implícito la interdisciplinaridad. Los estudiantes tienen contacto directo con profesionales de diversas disciplinas.
Ejemplaridad	La interacción con los profesionales de las empresas logran un proceso de intercambio de conocimientos con los estudiantes.
Relación entre teoría y práctica	Los cursos de ingeniería se diseñan para lograr las relación entre la teoría y la práctica
Aprendizaje basado en el trabajo de grupos	El proyecto se desarrolla en equipos de 3 a 5 estudiantes.

Fuente Propia

En la Tabla 3: Resumen de participantes en el estudio análisis de impacto, se detalla la cantidad de participantes en el estudio. Se aplicaron encuestas vía correo electrónico para estudiantes y egresados, telefónicas para los representantes de las empresas y talleres y reuniones con los profesores. Se ha fortalecido el aprendizaje entre iguales a través de sesiones llamadas Intercambio tecnológico, donde los estudiantes muestran a sus compañeros las soluciones técnicas encontradas y discuten y comparten el conocimiento.

A la pregunta realizada a las empresas sobre las principales fortalezas, ocupan el primer lugar las que se relacionan con habilidades blandas (Nichols, (2003))como son profesionalismo, puntualidad, aspectos éticos, motivación de los estudiantes (58%), En segundo lugar, con 21% lo ocupan las habilidades técnicas y de formación profesional porcentaje, para un total de 79% de respuestas enfatizando las fortalezas de los estudiantes. Lo anterior es consistente con la metodología del Aprendizaje Basado en Problemas, donde el aprendizaje significativo se visualiza en el empoderamiento de los estudiantes con relación al problema y su solución (Branda, 2001), se percibe un perfil integral de estudiante como ingeniero de sistemas.

La definición del proyecto como un medio de aprendizaje integral y un rol de facilitador del profesor ha favorecido el empoderamiento de los estudiantes que se apropian de la solución como lo muestran los resultados de autoevaluación y coevaluación de los aprendizajes, realizados durante los cursos. Los estudiantes son los que se relacionan directamente con las personas encargadas en las empresas, son los líderes técnicos y el profesor guía el proceso desde la perspectiva de la administración de proyectos.

Las diferentes y variadas soluciones técnicas a los problemas reales de los proyectos, presentan limitaciones en las empresas de presupuesto, equipo o habilidades. Los proyectos que se desarrollan tienen particularidades técnicas y alternativas de soluciones variadas, incluso opuestas y muchas veces no son de la especialidad del profesor, esto ha llevado a incrementar las necesidades de investigación y exploración por parte de los estudiantes.

Tabla 3: Resumen de participantes en el estudio análisis de impacto

Participantes	Con información de contacto	Muestra	Completaron los instrumentos
Estudiantes Ingeniería Sistemas I	140	140	118
Estudiantes Ingeniería Sistemas III	146	146	92
Egresados	461	207	43
Profesores	7	7	7
Representantes de empresas	80	48	19

Fuente (Sandoval, 2014)

3 Resultados, análisis y discusión

Se presentan a continuación los datos de la evaluación de proceso. Uno de los logros tangibles de la formalización de la aplicación del POPBL fue la inclusión, a partir del I semestre de 2009, del resumen de la metodología utilizada en la carta al estudiante o programa del curso. Con el fin de minimizar la percepción de un cambio profundo en la filosofía actual, se enfatizó inicialmente en el análisis que se muestra en la Tabla 2 Análisis comparativo POPBL- Prácticas de la Cátedra. Se realizaron reuniones con los académicos dando énfasis a los aspectos que ya se utilizaban en la cátedra, ya que de manera espontánea desde el 2006 se ha utilizado empíricamente este enfoque metodológico. Este análisis permitió realizar ajustes acordes con la realidad de la UNA.

Se promueve que los profesores impartan los tres cursos Ingeniería de Sistemas I, II y III con el fin de que posean una visión integral de los contenidos, metodología, proyectos y expectativas de cada materia. Además se realiza un taller anual de lecciones aprendidas, con los académicos donde se persigue mantener el enfoque en el POPBL, se revisan las actividades desarrolladas dentro y fuera del aula y su relación con la metodología de aprendizaje.

Ha sido posible consolidar material y formas de coordinación similares entre los profesores de un mismo curso en un nivel y un hilo conductor entre los 3 cursos de diferentes niveles. Los profesores de la cátedra mantienen un ambiente colaborativo que permite una retroalimentación profesional y constante para mantenerse en la dirección deseada y realizar los ajustes necesarios.

Considerando que los profesores y profesoras que imparten estos cursos provienen en su mayoría de la industria, y continúan laborando en ella, no siendo formadores de profesión, pero si con varios años de experiencia impartiendo clases, el enfoque de los cursos hacia el desarrollo de software en una empresa real, resultó natural.

No ha sido difícil para los profesores visualizar a los equipos de estudiantes como grupos de desarrolladores pues se desempeñan diariamente, en contextos como son usuarios insatisfechos, conflictos por trabajo multidisciplinarios, definiciones deficientes de necesidades de las organizaciones, presupuestos limitados, prioridades cambiantes etc., problemas que abundan en la literatura sobre los factores que afectan los proyectos de desarrollo de software.

Con respecto a los egresados de los curso un 89% afirma que las habilidades que aprendieron en los cursos de Ingeniería I, II y III son aplicables al mundo real. Cuando se preguntó qué les gusta del curso ambos grupos Ingeniería de Sistemas I (30%) e Ingeniería de Sistemas III (26%) colocan en primer lugar el contacto con el mundo real, igualmente ambos grupos ubican la experiencia laboral que les ofrece la experiencia en segundo lugar con 25% y 11% respectivamente.

Los cambios en el trabajo en el aula han sido substanciales. El semestre se compone de 17 semanas, de las cuales, tradicionalmente un 95% se dedicaban a clases tradicionales presenciales. Actualmente se han disminuido las clases magistrales y se ha incrementado las sesiones tipo taller y de supervisión. De acuerdo al avance del proyecto y su nivel de complejidad en los cursos así aumenta el porcentaje de sesiones de supervisión. Estas nuevas sesiones son en Ingeniería de sistemas I un 30%, un 40% en Ingeniería II y casi un 60% en Ingeniería III. Se modificó la forma de llevar a cabo la supervisión por parte de los profesores enfatizando en la utilización de mejores prácticas de administración de proyectos y la autonomía de los grupos de estudiantes.

Por otro lado la mayoría de las actividades del aula se desarrollan alrededor del proyecto, los contenidos del curso se vinculan con este, se promueve la reflexión, la autocrítica y la crítica, se realizan sesiones de análisis de situaciones particulares de los grupos, se han creado foros virtuales de discusión para consultas técnicas y aportes entre los estudiantes, dando énfasis al aprendizaje entre pares.

En otros aspectos son los estudiantes los que plantean su propio código de ética, resuelven sus conflictos, plantean a los profesores el problema con sus respectivas opciones de solución y recomendación. Actividades como la autoevaluación, coevaluación, elaboración de ensayos por parte de los estudiantes propician proceso de reflexión al finalizar los tres cursos.

Otro de los cambios que se han dado a raíz de la nueva filosofía, se relaciona con las evaluaciones del curso, anteriormente el mayor porcentaje lo representaban los exámenes escritos, actualmente el porcentaje asignado al proyecto, es el mayor y se ha incrementado como se muestra en la Tabla 4 Distribución de las evaluaciones antes y después de la formalización del POPBL.

Tabla 4: Distribución de las evaluaciones antes y después de la formalización del POPBL

Ingeniería de Sistemas	% Evaluación del proyecto **ANTES** de POPBL	% Evaluación del proyecto **DESPUES** de POPBL	% Evaluación de exámenes escritos **ANTES** del POPBL	% Evaluación de exámenes escritos **DESPUES** de POPBL
I	30	50	45	30
II	30	60	30	25
III	30	65	30	20

Fuente programas de cursos Ingeniería de Sistemas I, II y II

4 Conclusiones

Se logró que profesores con muchos años de experiencia profesional y formativa reconocieran la necesidad de reaprender su nuevo rol como docentes. Las semejanzas del trabajo realizado con los principios teóricos del POPBL motivaron más a los profesores en el proceso de cambio. Lograr una implementación bottom-up del POPBL fue posible y se ha mantenido durante casi 10 años gracias al trabajo de estos profesores y al ambiente colaborativo generado por el compromiso y logros obtenidos.

Los estudiantes entrevistados ponen en los dos primeros lugares de desarrollo, las habilidades asociadas con el trabajo en equipo y la administración. Estas habilidades no se relacionan con la programación, análisis o diseño, por lo que la reflexión de aprendizaje en los estudiantes va de lo técnico a las competencias hacia un nivel más integral.

Tanto estudiantes, egresados y empresas establecen la necesidad de reforzar las habilidades liderazgo, administración de proyectos y trabajo en equipo. Además es consiste en los participantes que se requiere profundizaren las labores de supervisión de los profesores.

Adicionalmente, se evidencia un porcentaje alto de satisfacción por el logro obtenido al finalizar el proyecto e implementar un sistema de información en la empresa, aspectos necesarios para lograr un clima de aprendizaje efectivo.

Una de las principales manifestaciones del cambio de paradigmas en los profesores, es ser un observador de muchas de las soluciones que proponen los estudiantes, ya que estos últimos poseen en muchas oportunidades más criterios y conocimiento de la problemática que técnica que los docentes. Profesor y estudiante trabajan con la incertidumbre, situación que refleja la realidad en las decisiones asociadas a las TIC. Es un cambio de profesor que tiene todo el conocimiento a profesor que aprende y empodera a sus estudiantes hacia una solución particular.

El trabajo en equipo se promueve en los estudiantes, uno de los principales logros es que a través del ejemplo que el mismo grupo de académicos vive propicia un clima apropiado para las mejorar y cambios. La experiencia ha beneficiado a empresas, que están satisfechas, por lo que repiten la colaboración y los estudiantes perciben que han aprendido y aportan al país.

Existen muchos retos de mejora continua como más formación para los profesores, fortalecer la evaluación individual de los estudiantes, revisión constante del rumbo. Sobre todo lograr que el cambio de paradigma sea aplicado la mayoría de cursos de la UNA, hacia un proceso de aprendizaje centrado en el estudiante, aunado al desarrollo de competencias para facilitar el desarrollo humano integral en la transformación positiva de la sociedad.

Los estudiantes trabajan en un ambiente independiente de manera activa en su aprendizaje, con empoderamiento y apropiación del proyecto y de los problemas reales que se le presentan, los profesores concluyen que con este enfoque centrado en el estudiante han avanzado considerablemente sin embargo no han involucrado, lo suficiente, al estudiante en el POPBL como teoría de aprendizaje.

El éxito de proyectos universidad–industria y el proceso de aprendizaje, empoderan a los estudiantes, retroalimentan las mejoras a los planes de estudio, facilitan el proceso de aprendizaje a través del contacto con una organización y contribuyen al desarrollo de las organizaciones.

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PBL in Systems Engineering Education: the Students' Perspective

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Abstract

Assessment of educational innovation efforts must be integral. Among other, it is necessary to consider students' perspective on the impact of educational innovation in their formation. This becomes even more critical if educational innovation efforts include the use of a model like the Problem Based Learning. This paper presents the results of a survey study made in a context where problems take form of software development projects, made by systems engineering students in real contexts. The study aims to measure the impact of the implementation of the PBL model in the formative process of system engineering students. The study was conducted by considering regular students of the National University (UNA) in Costa Rica. Data collection was face to face with the students and measured various aspects of the students' perspective on the educational model. Results suggest a high motivation and a positive effect on students. Their willingness to learn, apply knowledge and develop their skills in developing real software engineering projects, was identified as relevant results of the educative process. Student's satisfaction is evidenced by the achievement obtained to complete the project and implement the software. The assessment of the skills varied throughout the educative process. However, aspects as the project management, leadership, and team work maintain a high valuation and are fundamental pillars for the implementation of the development methodology used during courses.

Keywords: Problem Based Learning; PBL; systems engineering education; students' perspective.

PBL en la Enseñanza de la Ingeniería de Sistemas: la Perspectiva de los Estudiantes

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Abstract

La evaluación de los resultados de la innovación educativa debe ser integral. Entre otros elementos a considerar, destaca la perspectiva de los estudiantes sobre el impacto que tiene la innovación educativa en su formación. Esto se vuelve todavía más crítico si los esfuerzos de innovación educativa incluyen el uso de un modelo como el Aprendizaje Basado en Problemas (PBL por sus siglas en Ingles). En este artículo presentamos los resultados de un estudio hecho en un contexto donde la solución de problemas toma la forma de proyectos de desarrollo de software, implementados por estudiantes de ingeniería de sistemas, en contextos reales. El estudio fue una encuesta hecha con el fin de medir el impacto de la implementación del modelo PBL, en estudiantes de ingeniería de sistemas. El estudio fue hecho considerando estudiantes regulares de Ingeniería de Sistemas de la Universidad Nacional (UNA) en Costa Rica. La recolección de datos fue presencial y se enfocó en medir la perspectiva de los estudiantes sobre diversos aspectos relacionados con el modelo educativo. Los resultados del estudio sugieren una alta motivación y un efecto positivo en el estudiante por su disposición por aprender, aplicar el conocimiento y desarrollar sus habilidades en el desarrollo de proyectos reales de ingeniería de software. Se evidencia un porcentaje alto de satisfacción por el logro obtenido al finalizar el proyecto e implementar un sistema de información en la industria. La valoración de las habilidades varió a lo largo del proceso de enseñanza, sin embargo, administración de proyectos, liderazgo y trabajo en equipo, mantienen una alta valoración y son pilares fundamentales para la aplicación de la metodología de desarrollo utilizada durante los cursos.

Keywords: Aprendizaje basado en problemas; PBL; educación en ingeniería de sistemas; perspectiva de estudiantes.

1 Introduction

En el caso que exponemos en este artículo, la solución de problemas toma la forma de proyectos de desarrollo de software, desarrollados por estudiantes de ingeniería de sistemas, que solucionan problemas reales en contextos específicos. Este artículo reporta los resultados de una encuesta hecha en estudiantes que han participado en una implementación de PBL en un programa académico a nivel de grado en Ingeniería de Sistemas. El objetivo del estudio fue explorar la perspectiva de los estudiantes respecto al efecto del modelo PBL en su proceso de aprendizaje, la relación con el facilitador y la relación con el contexto donde el problema se ubica.

Los resultados del estudio sugieren una alta motivación y un efecto positivo en el estudiante por su disposición por aprender, aplicar el conocimiento y desarrollar sus habilidades en el desarrollo de proyectos reales de ingeniería de software. Se evidencia un porcentaje alto de satisfacción por el logro obtenido al finalizar el proyecto e implementar un sistema de información en la industria. La valoración de las habilidades varió a lo largo del proceso de enseñanza, sin embargo, administración de proyectos, liderazgo y trabajo en equipo, mantienen una alta valoración y son pilares fundamentales para la aplicación de la metodología de desarrollo utilizada durante los cursos.

En el apartado 2 se presenta una revisión de literatura relacionada con el estudio. Posteriormente, en el apartado 3 se describe el método utilizado en el desarrollo del estudio. Aquí se detallan el contexto del estudio, procedimiento, participantes, colección de datos y como fue hecho el análisis. El apartado 4 por su parte muestra los resultados obtenidos los cuales son analizados en esta misma sección. Finalmente, en el apartado 5 se presentan las conclusiones del estudio, limitaciones y trabajos futuros.

La evaluación de los resultados de la innovación educativa debe ser integral. Entre otros elementos a considerar, destaca la perspectiva de los estudiantes sobre el impacto que tiene la innovación educativa en su formación. Esto se vuelve todavía más crítico si los esfuerzos de innovación educativa incluyen el uso de un modelo como el Aprendizaje Basado en Problemas (PBL por sus siglas en Ingles) (Bell, 2010)

En este paradigma de aprendizaje, los estudiantes son protagonistas del proceso de formación por medio de la solución de problemas reales (Branda, Aprendizaje basado en problemas, centrado en el estudiante, orientado a la comunidad. Universidad de Canadá., 2001). Este hecho motiva a prestar especial atención a la perspectiva de los estudiantes que se ven inmersos en un proceso de innovación educativa (Qvist, 2009), que en el modelo PBL está centrado en el estudiante y lo lleva a ser responsable de su propio aprendizaje y por tanto su autorreflexión es útil para los involucrados en el proceso.

Saez (2008), Bell (2010) , Lehman (2008) concluyen que el proceso de enseñanza-aprendizaje a través del PBL es más eficiente que usando sistemas más tradicionales y uno de los parámetros de medición lo representa la percepción del estudiante. (Lehmann M. C., 2008)

2 Método

Durante más de 10 años se han aplicado elementos del PBL en los cursos de Ingeniería de Sistemas de la UNA, por lo que se hacía necesario contar con realimentación proveniente de un estudio con un nivel de rigurosidad que permitiera el desarrollo de mejoras y la actualización de los elementos que componen el proceso de aprendizaje. La consulta directa a los estudiantes se desarrolló a través de una encuesta aplicada en forma presencial. El diseño se basó principalmente en los objetivos de aprendizaje de los cursos, la forma de abordar los proyectos y la relación entre las partes: estudiantes, profesores y empresas.

2.1 El Contexto del Estudio

La carrera de Ingeniería de Sistemas es impartida, desde 1985, por la Escuela de Informática de la Universidad Nacional, cuenta con aproximadamente 1300 estudiantes. En el 2005 fue la primera carrera de informática acreditada en el país por el Sistema Nacional de Acreditación de la Educación Superior (SINAES).

De acuerdo con el plan de estudios del bachillerato en Ingeniería de Sistemas-2004 de la UNA, el estudiante en esta carrera debe ser "intelectualmente inquieto", es decir, debe investigar guiado por el docente o por sí mismo, pues esta carrera demanda una actualización constante (Coto, 2005). De esta forma, se concibe al estudiante en los cursos de Ingeniería de Sistemas en un rol participativo y activo en el proceso de aprendizaje: debe identificar los problemas, investigar, presentar alternativas de solución, buscar asesoría, consultar ejemplos de casos similares, comunicar ideas y plasmar resultados en los productos del proyecto.

La principal estrategia metodológica implementada en los cursos de Ingeniería de Sistemas es el aprendizaje basado en proyectos. PBL por sus siglas en inglés (Problem Based Learning) y específicamente una de sus variantes como lo es el aprendizaje basado en problemas orientado a proyectos, POPBL por sus siglas en inglés Project Oriented Problem Based Learning. (Lehmann M. C., 2008)

El problema a resolver es el desarrollo de un sistema de información en una empresa real, los estudiantes se enfrentan al manejo de conflictos del equipo de trabajo y a la relación con la Empresa para determinar sus necesidades de información y de procesamiento que deben ser resueltas mediante un sistema de información desarrollado y estabilizado al finalizar los tres ciclos. Cada problema es diferente debido al contexto en el cual se desarrolla, por ejemplo, la cultura organizacional, los usuarios, el tipo de sistema; por lo tanto, las situaciones a resolver no siempre son predecibles ni su solución se puede presentar de manera estructurada ni completa, lo cual conlleva al estudiante a buscar información, discutir y tratar de resolver el problema.

Los elementos principales de este proceso son: -los estudiantes, -el problema a resolver, -las empresas y -los profesores. Los estudiantes se organizan en grupos de trabajo de 3 o 4 integrantes, cuyo grupo se mantiene durante todo el desarrollo del proyecto, es decir, durante tres semestres en los cuales se imparten los cursos de Ingeniería de Sistemas I, II y III. El problema y la empresa son propuestas por cada grupo de estudiantes, quienes realizan la búsqueda por cuenta propia. Estas propuestas son analizadas por los profesores, quienes, en conjunto con los estudiantes, seleccionan la empresa.   Finalmente, la Cátedra de Ingeniería de Sistemas asigna un profesor para la supervisión de cada proyecto.

La empresa puede ser una empresa pública, privada, grande o pequeña, algunas cuentan con un departamento de Tecnología de Información, otras no; sin embargo, hay requisitos que estas deben cumplir, como por ejemplo: asignar tiempo parcial de los funcionarios que se relacionan con el problema a resolver y aportar los recursos técnicos tales como el equipo, el software base y el espacio físico que se requiere para ubicar los estudiantes, realizar reuniones, realizar pruebas y capacitación, entre otros.

Las principales funciones de supervisor son: guiar a los estudiantes en la administración del proyecto, asignar y revisar cada uno de los productos, reforzar conceptos, aplicar su experiencia para dirigir el proyecto, guiar en la resolución de conflictos y distribución de cargas entre los estudiantes.

2.2 Procedimiento

Para la recopilación de datos y análisis de resultados se utilizaron técnicas cuantitativas y cualitativas aplicando métodos mixtos, lo cual supone un tipo específico de diseño, diferente del puramente cuantitativo o cualitativo (Verd Joan, 2007).

La encuesta consideró los objetivos de aprendizaje de cada curso, fue aplicada por los profesores de los cursos de Ingeniería de Sistemas I y III a sus estudiantes durante la última clase del curso, se aplicó en forma presencial mediante el documento impreso. Se leyeron las instrucciones generales y se les dio un espacio de cuarenta y cinco minutos para completarla.

2.3 Participantes

La investigación se limita a los alumnos de los cursos. Se diseñaron dos encuestas diferentes, considerando que cada grupo posee objetivos de aprendizaje distintos: una para el grupo de estudiantes de Ingeniería I (I1) y otra para el grupo de estudiantes de Ingeniería III (I3).

Los participantes de cada uno grupo tienen características similares en currículo, experiencia en el contexto, edad y género.

Específicamente, en el caso del grupo I1, los estudiantes han obtenido el 62% de los créditos del grado. La experiencia acumulada en el contexto es de 6 meses. La edad promedio es de 20 años y el porcentaje de mujeres es de 20%.

Por su parte, en el caso del grupo I3, los estudiantes han acumulado el 87% de los créditos del grado. La experiencia es de 18 meses. Adicionalmente, en este grupo de estudiantes el 87% normalmente tienen, en paralelo a su proceso de formación académica, un trabajo formal relacionado con el desarrollo de software La edad promedio 22 años (DE=2.13). El porcentaje de mujeres 17%.

La encuesta fue entregada a 145 estudiantes de ingeniería I y 146 de ingeniería III), de los cuales respondieron 118 de Ingeniería I (81%) y 92 de Ingeniería III (63%).

2.4 Colección de Datos

La encuesta de I1 contiene 29 preguntas cerradas y 3 abiertas, mientras que la de Ingeniería III estuvo conformada por 31 preguntas cerradas y 3 abiertas. Las preguntas cerradas se enfocaron en recolectar datos relacionados con variables preestablecidas tales como efecto en el aprendizaje, relación con el facilitador y relación con la empresa patrocinadora. Las preguntas abiertas se utilizaron para reforzar las conclusiones resultantes del análisis de las preguntas cerradas.

2.5 Análisis Desarrollado en el Estudio.

Los datos fueron revisados para clarificar y depurar la información proporcionada por los participantes. Para analizar los resultados se agruparon las preguntas de acuerdo con las variables definidas. Se tabularon los datos, se generaron totales, distribuciones de frecuencias, promedios, porcentajes, etc. Los resultados de las diferentes variables fueron analizados por separado y en algunos casos se agruparon para consolidar los hallazgos.

En el caso de las preguntas abiertas se utilizaron algunos principios de "grounded theory" (Strauss & Corbin, 1998), por ejemplo, se identificaron patrones de categorías de conceptos para cuantificar las opiniones vertidas por los participantes. (Strauss, 1998).

3 Resultados y Análisis

3.1 Efecto en el Aprendizaje del Estudiante

El análisis del efecto se enfocó en la percepción de las habilidades adquiridas y la motivación. En un proceso de aprendizaje, la motivación es un aspecto fundamental, tanto en el aprendiz como en el facilitador. La aplicación del conocimiento mediante un proyecto de la vida real, según Branda (2001) motiva al estudiante para aprender, pues no se detiene en un caso ficticio o un simulacro, sino que le permite vivir el proceso y desarrollar sus propias habilidades.

3.2 Motivación del Estudiante

En la Tabla 1 se muestra el resultado de las preguntas relacionadas con la motivación, identidad con el proyecto y satisfacción con el trabajo realizado.

Los resultados del estudio reflejan una alta motivación y un efecto positivo en cuanto a la disposición por aprender y aplicar el conocimiento y las habilidades, por cuanto un 97% y un 99%, respectivamente, responden en forma positiva ante la pregunta de si le gustó trabajar en el proyecto como una experiencia y contacto con el mundo real y si las habilidades aprendidas son aplicables al mundo real. Cuando se les pregunta si se sienten satisfechos con el progreso que tiene hasta ahora el proyecto, el 88% responde estar de acuerdo.

Tabla 1: Motivación del estudiante en relación con su proyecto de la vida real

Pregunta	Totalmente de acuerdo	De acuerdo	En desacuerdo	Totalmente en desacuerdo
Me gusta trabajar en el proyecto como una experiencia y contacto con el mundo real	78%	21%	0%	1%
Las habilidades aprendidas son aplicables al mundo real	61%	38%	1%	0%
Estoy convencido (a) de que mi equipo entregará un sistema que se utilizará y satisfacerá las necesidades del cliente	72%	26%	0%	1%
Estoy satisfecho con el progreso que tiene hasta ahora el proyecto	46%	42%	9%	2%
Hicieron el mejor trabajo que podrían realizar durante toda la participación en el proyecto	53%	36%	9%	2%

Tómese en cuenta que en el momento en que se realiza la pregunta, los estudiantes de I1 los proyectos llevan un ciclo de haber iniciado, es decir, que aún faltan dos tercios para su finalización; sin embargo, se percibe entusiasmo y positivismo con respecto su éxito, lo cual prevalece si se compara con el resultado de la evaluación de los estudiantes de I3, pues el 89% considera que siempre hicieron el mejor trabajo que podrían realizar durante toda la participación en el proyecto. Lo anterior coincide con la filosofía del aprendizaje basado en problemas utilizado en los cursos de Ingeniería de Sistemas.

3.3 Preferencias del Estudiante

Ante la pregunta abierta qué les gusta de este curso, los estudiantes de ingeniería de Sistemas I responden en los siguientes términos: el 30% señaló aspectos relacionados con el contacto con el mundo real, el 25% con la preparación como experiencia laboral, el 14% con administración de proyectos, el 10% con el trabajo en equipo, el 14% otros aspectos y el 7% no respondió. Por otra parte, los estudiantes de ingeniería III señalan: el 26% aspectos relacionados con el contacto con el mundo real, el 15% sobre la preparación como experiencia laboral, el 11% la satisfacción por implementar el sistema en una empresa, el 10% la administración de proyectos, el 8% el trabajo en equipo, el 3% programación, el 16% se refirió a otros aspectos difíciles de agrupar para su análisis y el 11% no respondió.

Lo anterior refleja un alto interés del estudiante en la experiencia con el mundo real y el contacto con la empresa como una preparación para su vida laboral. Adicionalmente, se evidencia un porcentaje alto de satisfacción por el logro obtenido al finalizar el proyecto e implementar un sistema de información en la empresa.

3.4 Habilidades Adquiridas por el Estudiante

Los estudiantes calificaron las habilidades adquiridas en los cursos de Ingeniería I y III, asignando un puntaje de 1 a 10, según su criterio, donde 1 era el puntaje más bajo y 10 correspondía a la habilidad que desarrolló en el curso con mayor intensidad. Las habilidades evaluadas fueron: redacción, conocer un método de desarrollo específico, trabajo en equipo, buenas prácticas de programación, administración de proyectos, liderazgo, habilidades y ética (confidencialidad, competencia, derechos de propiedad intelectual, uso apropiado de las habilidades técnicas), habilidades para documentar los procesos, especializarse en áreas puntuales del conocimiento informático (por ej. lenguajes, BD, telecomunicaciones, etc.), conocer técnicas modernas de depuración de programas.

Se le preguntó al estudiante: En su criterio, indique cuáles habilidades ha desarrollado más significativamente durante el curso, ordénelas de 1 a 10, donde 10 es el más significativo y 1 el menos significativo. Para procesar los datos se sumó el puntaje brindado por los encuestados a cada habilidad, cuyos resultados se muestran la Figura 1. En esta figura, se ordenan las habilidades de mayor a menor puntaje obtenido y se relaciona el comportamiento de una habilidad entre los estudiantes de ingeniería I y III por medio de líneas punteadas --- cuando se mantienen o sube y flechas de color rojo cuando baja su valoración.

Los estudiantes del curso de I1 brindaron mayor puntaje a las habilidades: Trabajo en equipo, administración de proyectos, documentar procesos, ética y liderazgo. Mientras que los estudiantes del curso de I3, asignaron mayor puntaje a las habilidades: administración de proyectos, trabajo en equipo, buenas prácticas en programa y especialización en áreas puntuales del conocimiento informático (por ejemplo: lenguajes de programación, BD y telecomunicaciones).

La valoración de las habilidades varió de un curso a otro, por un lado se presentaron habilidades que aumentaron en posición al pasar del curso de I1 a I3 por ejemplo: especialización en áreas puntuales del conocimiento informático (pasó de la posición 7 a la posición 4) y buenas prácticas de programación (pasó de la posición 10 a la posición 3). Es comprensible que ambas habilidades aumenten en I3, pues en este curso los estudiantes desarrollan el código, por ende requieren y usan estas habilidades. Por otro lado, algunas habilidades disminuyeron su valoración, por ejemplo: habilidades para documentar procesos (pasó de la posición 3 a la posición 7), ética, confidencialidad, competencia, derechos de propiedad intelectual, uso inapropiado de las habilidades técnicas (pasó de la posición 4 a la posición 6), redacción (pasó de la posición 8 a la posición 10) y conocer un método de desarrollo específico (pasó de la posición 6 a la posición 8). Estas habilidades deberían mantenerse durante todos los cursos, pues en I3se documenta el proceso de testing, se realizan los manuales técnicos y de usuario y se mantienen los valores y principios de ética profesional. Al respecto, podría suponerse que son habilidades que se adquieren desde ingeniería I y que el estudiante de I3 las da por aprendidas, por lo tanto, las considera menos importantes.

Ingeniería I	Puntaje (Ing.I)
c. Trabajo en equipo	849
e. Administración de proyectos	817
h. Habilidades para documentar los procesos.	793
g. Habilidades y ética (confidencialidad, competencia, derechos de propiedad intelectual, uso apropiado de las habilidades técnicas).	777
f. Liderazgo	705
b. Conocer un método de desarrollo específico.	681
i. Especializarse en áreas puntuales del conocimiento informático (por ej. lenguajes, BD, telecomunicaciones, etc.)	595
a. Redacción	595
j. Conocer técnicas modernas de depuración de programas.	529
d. Buenas prácticas de programación.	515

Puntaje (Ing.III)	Ingeniería III
710	e. Administración de proyectos
611	c. Trabajo en equipo
573	d. Buenas prácticas de programación.
552	i. Especializarse en áreas puntuales del conocimiento informático (por ej. lenguajes, BD, telecomunicaciones, etc.)
551	f. Liderazgo
508	g. Habilidades y ética (confidencialidad, competencia, derechos de propiedad intelectual, uso apropiado de las habilidades técnicas).
499	h. Habilidades para documentar los procesos.
482	b. Conocer un método de desarrollo específico.
447	j. Conocer técnicas modernas de depuración de programas.
408	a. Redacción

Figura 1: Percepción de las habilidades de los estudiantes desarrolladas durante los cursos de Ingeniería de Sistemas I y III

Otras aspectos como: administración de proyectos, liderazgo y trabajo en equipo se mantienen en su valoración, pues en ambos cursos se imparten temas relacionados con administración de proyectos y esta disciplina prevalece durante las cuatro fases de la metodología utilizada- Proceso Unificado. A los estudiantes de ingeniería III se les preguntó si consideran que han adquirido habilidades para el trabajo en equipo por medio de la participación en el proyecto, el 62% respondió estar totalmente de acuerdo, el 27% de acuerdo, el 6% en desacuerdo, el 4% totalmente en desacuerdo y el 1% no respondió. Este resultado refleja un convencimiento sobre la habilidad adquirida para trabajar en equipo.

Conocer técnicas modernas de depuración de programas es una habilidad que los estudiantes no utilizan en el curso de Ingeniería I, sino hasta que inician la construcción del sistema, actividad que se presenta más fuertemente en el curso de Ingeniería III, lo cual permite concluir que la valoración es adecuada.

En relación con la pregunta qué le faltó antes del curso de Ingeniería III, el 15% respondió en función de las habilidades liderazgo, administración de proyectos y trabajo en equipo, mientras que se les preguntó –Qué les faltó en el curso- y solamente el 4% respondió en función de ellas. Adicionalmente, los estudiantes consideran que uno de principales factores que incidieron negativamente en su proyecto fueron “subestimar la dimensión del proyecto”, “inadecuada administración” y “desviación del alcance original”. Por lo tanto, se puede intuir que debería reforzarse la supervisión, dirección y control del proyecto.

3.5 Relación con el Profesor Tutor del Proyecto

La comunicación entre el profesor tutor y el estudiante se analiza desde dos perspectivas: la colaboración y disposición que brinda el estudiante hacia su profesor (a) y la que brinda el profesor (a) a sus estudiantes durante la supervisión del proyecto. En la primera perspectiva el 91% de los estudiantes de ingeniería I consideran que brindaron una colaboración efectiva, eficaz y útil a los profesores; mientras que en la segunda perspectiva el 84% considera que la colaboración y el aporte de los profesores de la cátedra de Ing. De Sistemas ha sido efectiva, eficaz y útil. En ambos casos el 1% no responde, el 9% considera que no brindaron la colaboración efectiva, eficaz y útil a los profesores y el 14% considera que la colaboración y aporte recibido no fue del todo efectivo, eficaz y útil. Adicionalmente el 88% de los estudiantes de ingeniería I comprenden las contribuciones y los aportes del profesor titular a su proyecto.

Si se analiza el criterio de los estudiantes de ingeniería III, el 87% considera que su profesor(a) titular ha tenido una comunicación efectiva durante todo el proceso, el 79% están de acuerdo con que los miembros del equipo consideran que el/la profesor/a titular utiliza eficazmente las habilidades como comunicador y el 88% afirman que sus profesores (as) colaboraron para comprender cuáles eran sus responsabilidades en el proyecto. Estos resultados reflejan una buena participación de los profesores en el proyecto, congruente con el rol del docente que se define en el plan de estudios de la Escuela de Informática.

A los estudiantes de ingeniería I se les preguntó si sienten que están trabajando con un buen equipo de proyecto (incluye estudiantes, profesores y empresa), el 51% estuvo totalmente de acuerdo, el 41% estuvo de acuerdo, el 6% en desacuerdo, el 1% en total desacuerdo y el 1% no respondió. Esta valoración refleja un clima conveniente entre el equipo de trabajo UNA-Industria, específicamente profesor-estudiante-empresa, para una adecuada realización del proyecto.

3.6 Relación con la Empresa

Los profesores conocen la importancia que tiene una buena relación entre -la empresa y -los estudiantes, así como su incidencia tanto en el éxito del proyecto como en el proceso de aprendizaje. Por una parte, a los estudiantes de ingeniería I se les preguntó si su equipo interactuó con el cliente en un ambiente profesional y una adecuada provisión de lo necesario, el 52% indicó estar totalmente de acuerdo, el 43% de acuerdo, el 4% en desacuerdo y el 1% totalmente en desacuerdo. Se les preguntó si la comunicación entre su equipo y el cliente ha sido rápida y sin contratiempos molestos, el 42% estuvo totalmente de acuerdo, el 42% de acuerdo, el 14% en desacuerdo y el 2% en total desacuerdo. Adicionalmente, el 98% considera que el cliente estaba satisfecho con el plan del proyecto. Por otra parte, a los estudiantes de ingeniería III se les preguntó: según la experiencia en los cursos de Ingeniería de Sistemas I, II y III, ¿Qué factores afectaron negativamente a su proyecto?, se brindaron 10 opciones para su valoración, donde calificaron con 10 al factor que afectó más negativamente a su proyecto. En la Tabla 2 se observan los factores y la valoración brindada.

Los aspectos más relacionados con administración de proyectos: "subestimar la dimensión del proyecto", "falta de supervisión, dirección y control del proyecto (inadecuada administración de proyectos)", "desviación del alcance original" e "inadecuadas estimaciones" fueron valorados como los aspectos más negativos que les afectó en su proyecto, posición 10, 9, 8 y 7 respectivamente; por lo tanto, se puede concluir que debería reforzarse la supervisión, dirección y control del proyecto. Los otros aspectos valorados fueron: inadecuados conocimientos técnicos, actitud, pro actividad y habilidad de cada uno de los miembros del grupo de trabajo (posición 6), en la posición 5: inadecuado Interés, dedicación y participación activa de la empresa patrocinadora y de los usuarios; 4: cambios organizacionales de la empresa patrocinadora; 3: fallas en los recursos básicos tales como espacio para reuniones, equipo de desarrollo, el espacio físico, proyector, fotocopias, alimentación, equipo y software en el momento requerido; 2: mala comunicación entre el grupo de trabajo y la empresa patrocinadora y metodología inadecuada (posición 1).

En forma general, la relación estudiante-empresa es muy buena, considerando que esta es un factor crítico en los proyectos de ingeniería de software, sin embargo, los estudiantes consideran que el entorno organizacional y la relación con la empresa desfavorables inciden negativamente en el proyecto (posición 8), podría realizarse un seguimiento más cercano a los proyectos con el propósito de identificar de una forma más precisa, las variables que estén afectando y los ajustes que se requiere realizar en la administración de los proyectos.

Tabla 2: Factores que inciden negativamente en el éxito de su proyecto, según el criterio de los estudiantes del curso: Ingeniería III

Factor evaluado	Puntaje Obtenido	Posición
Subestimar la dimensión del proyecto.	565	10
Falta de supervisión, dirección y control del proyecto (Inadecuada administración de proyectos)	529	9
Desviación del alcance original del proyecto. Entorno organizacional de la empresa patrocinadora	510	8
estimaciones inadecuadas	489	7
Inadecuados conocimientos técnicos, actitud, proactividad y habilidad de cada uno de los miembros del grupo de trabajo	461	6
Inadecuado Interés, dedicación y participación activa de la Empresa patrocinadora y de los usuarios	457	5
Cambios organizacionales de la empresa patrocinadora	452	4
Fallas en los recursos básicos tales como espacio para reuniones, equipo de desarrollo, el espacio físico, proyector, fotocopias, alimentación, equipo y software en el momento requerido	449	3
Mala comunicación entre el grupo de trabajo y la empresa patrocinadora	448	2
Metodología inadecuada	386	1

A los estudiantes de ingeniería I se les preguntó si sienten que están trabajando con un buen equipo de proyecto (incluye estudiantes, profesores y empresa), el 51% estuvo totalmente de acuerdo, el 41% estuvo de acuerdo, el 6% en desacuerdo, el 1% en total desacuerdo y el 1% no respondió. Esta valoración refleja un clima conveniente entre el equipo de trabajo UNA-Industria, específicamente profesor-estudiante-empresa, para una adecuada realización del proyecto.

4 Conclusiones

En este artículo se presentaron los resultados de una encuesta hecha a estudiantes de ingeniería de sistemas, con el fin de medir el impacto de la implementación del modelo PBL. El estudio fue hecho en la Universidad Nacional (UNA) en Costa Rica.

Los resultados del estudio reflejan una alta motivación y un efecto positivo en el estudiante por su disposición por aprender, aplicar el conocimiento y desarrollar sus habilidades durante los proyectos reales de ingeniería de software. Se evidencia un porcentaje alto de satisfacción por el logro obtenido al finalizar el proyecto de implementar un sistema de información en la industria. La valoración de las habilidades varió de un curso a otro, sin embargo la administración de proyectos, el liderazgo y el trabajo en equipo, mantienen una alta valoración y son pilares fundamentales en la aplicación de la metodología de desarrollo utilizada: Proceso Unificado.

Los resultados relacionados con los que los estudiantes gustan del curso reflejan un alto interés del estudiante en la experiencia con el mundo real y el contacto con la empresa como una preparación para su vida laboral. Adicionalmente, se evidencia un porcentaje alto de satisfacción por el logro obtenido al finalizar el proyecto e implementar un sistema de información en la empresa, aspectos necesarios para lograr un clima de aprendizaje efectivo.

A partir de este estudio se sugiere realizar más estudios longitudinales con el fin de explorar aspectos que quedaron fueran de esta encuesta tales como el efecto del aprendizaje del modelo PBL en los estudiantes de Ingeniería de Software en la iniciación laboral y su aporte a la industria.

5 Agradecimientos

Este trabajo se realizó gracias al esfuerzo y compromiso de los profesores de la Catedra de Ingeniería de Sistemas, Escuela de Informática, Universidad Nacional, en Heredia, Costa Rica, así como al apoyo de la Universidad de Aalborg especialmente de las profesoras Heilyn Camacho, Marianne Lykke y Lone Dirckinck-Holmfeld.

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PBL: Are we forming skills? Formative Assessment?

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Abstract

In Problem Based Learning (PBL), an appropriate articulation of command of the subject, knowledge and management on didactic methodologies, as well as applying different forms of evaluation according to the context is essential. Evaluation is fundamental in the teaching-learning process. From the PBL perspective, its effectiveness depends on focus and putting it into practice, which includes permanent feedback processes. Let us remember that in PBL, the competency formation and that it has done not-over learning-but-for learning is essential. It's important to include qualitative evaluation to the process, for it offers rewarding information about each student development progressively. Because of the fact that there is a strong correlation between all factors that determine accomplishments motivation, it is complex to measure quantitatively the progress with this methodology. In 2013 a test was developed to look into how much knowledge does the apprentice has about the way he learns (goal-cognition). The hypothesis was that students that took a chemistry class using the group and PBL methodology are more aware of their metacognitive abilities. The test threw a Cronbach coefficient of 0.85, this test has been improved and now has an alfa of 0.88. This test has been applied to students before and after they take a class with PBL methodology, and there is a small but persistent positive difference in the results. However, there are still factor to account, like the natural increment in maturity during the semester and the predictive nature of retaking the test. Because we are aware the feedback plays a strong role in the teaching-learning process, an investigation has started in parallel (besides studying the influence in metacognition) about the quantitative contributions of feedback in accomplishments motivation; in which different evaluation matrixes are being used in the same process. The preliminary results are encouraging. The following article hopes to show the progress in both investigations.

Keywords: PBL and formative evaluation, feedback, PBL and competences.

ABP: ¿Formando en competencias? ¿Evaluación formativa?

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Resumen

En el aprendizaje basado en problemas (ABP), es primordial una adecuada articulación entre dominio del tema, manejo de metodologías didácticas y la aplicación de diversas formas de evaluación, acordes al contexto. Desde la perspectiva del ABP la evaluación es fundamental y, su efectividad, depende del enfoque y puesta en práctica del proceso enseñanza-aprendizaje. Esté, incluye permanente retroalimentación, recordemos que, evaluar implica formación en competencias y se debe realizar no -sobre el aprendizaje- sino –para el aprendizaje-. Es prioritario incorporar evaluación cualitativa al proceso ya que ofrece información enriquecedora del avance progresivo de cada estudiante. Existe fuerte interrelación entre los factores que determinan la motivación al logro, en consecuencia, resulta complejo determinar cuantitativamente qué se logra usando esta metodología. El año 2013 elaboré un test indagando acerca del conocimiento que tiene el aprendiz sobre la manera en que aprende (meta-cognición). La hipótesis planteada fue que los estudiantes que llevaron algún curso de Química con metodología grupal ABP conocen mejor sus habilidades metacognitivas. La prueba arrojo un coeficiente de Cronbach de 0,85, la prueba se ha mejorado, teniendo actualmente alfa de 0,88. Este test se ha venido aplicando a alumnos antes de llevar la metodología y al finalizan el curso usando ABP, se aprecia una diferencia pequeña pero persistente. Sin embargo, aún falta analizar factores como: el incremento natural de la madurez durante el transcurso del semestre y la capacidad predictiva de la prueba. Puesto que somos conscientes que la retroalimentación juega un papel predominante en este proceso, además de estudiar la influencia en la metacognición, se ha iniciado de forma paralela, la investigación cuantitativa acerca del aporte de la retroalimentación en la motivación al logro, para lo cual se están utilizando diferentes rúbricas del mismo proceso. Los resultados preliminares son alentadores. El presente artículo pretende mostrar los avances en ambas indagaciones.

Palabras claves: ABP y evaluación formativa, retroalimentación, ABP y competencias

1 Introducción

La metodología híbrida, basada en ABP, se aplica en los cursos de Química General desde 2006. Estos años se han realizado diversas innovaciones; implementación de mini-experiencias en el aula, sesiones experimentales con más autonomía, mayores oportunidades de retroalimentación, mayor participación en la co-evaluación, etc. Durante estos años, las encuestas confirman que, aplicando esta metodología, se obtienen más estudiantes promovidos y ratifica que prefieren este tipo de metodología a la tradicional. Pero, más allá de esos resultados cualitativos somos conscientes que, si nuestro objetivo es la formación en competencias, entonces, la evaluación es especialmente importante.

Recordemos que la evaluación, inherente al proceso de enseñanza-aprendizaje, tiene doble poder y aborda:

- Factores cognitivos, puesto que, brinda al estudiante la información que requiere para comprender la situación en que se encuentra respecto a su aprendizaje.

- Factores motivacionales, ya que le permite desarrollar mayor autonomía, haciendo posible la autorregulación de su aprendizaje y consecuentemente motivarlo.

Teniendo en cuenta ese doble poder, debemos ver la forma de aprovechar las oportunidades que brinda, por lo que la evaluación cualitativa se convierte en fundamental, al ser precisamente la que permite, que, con cada oportunidad, el estudiante pueda ir enriqueciéndose y mejorar su desempeño paulatinamente.

Los procesos involucrados son complejos, de allí la importancia que, la planificación y el diseño, se orienten hacia un enfoque evaluativo, donde estudiantes y docentes resulten beneficiados.

La meta es incorporar una -evaluación para el aprendizaje-que no solo permita medir los resultados obtenidos, sino que apuntale recursos y herramientas para mejorar el aprendizaje. Se intenta medir tanto cualitativa como cuantitativamente los impactos de las modificaciones en la didáctica empleada y en la forma de evaluación.

2 Marco de referencia

Uno de los principales aportes, de la educación superior, es su contribución a la *formación* de capital humano para que sea capaz de desempeñar roles claves para el desarrollo de los países. Las políticas educativas, impulsadas por la masificación de la universidad, conducen a la preocupación por mejorar la calidad de las instituciones de educación superior y las carreras que estas proponen, lo cual está dirigiendo a las universidades a hacer ajustes a sus currículos, pedagogía y recursos, de tal manera de hacer frente a una población estudiantil, que trae nuevas aspiraciones y menores calificaciones académicas. Esta situación demanda ajustes y enfoques diversos, no demasiado conservadores y que contemplen la *formación* en competencias y habilidades transversales tales como aprender a aprender, trabajo en equipo, solución de problemas, etc., que no suele contemplarse en currículos tradicionales.

Los cursos de Química general se dictan en el primer y tercer semestre académico. En La Universidad de Piura hace algunos años se viene cambiando la forma en que se obtienen las calificaciones. A pesar de seguir ingresando notas en las fechas programadas por la secretaria de la facultad, a nivel aula, se viene implementando metodología más apropiada para la evaluación formativa que se pretende. Se incorpora al estudiante en el trabajo activo- grupal y ABP de manera paulatina. Inician con un ciclo propedéutico, donde se realiza exposición acompañada de resolución de ejercicios y situaciones puntuales (50%-50%), procurando trabajar en parejas. El objetivo es iniciar al alumno en el trabajo con otros. Es un periodo de seis semanas intenso y la evaluación contempla, casi exclusivamente, aspectos cognitivos. En caso el estudiante no sea removido tiene la oportunidad de llevar un semestre llamado "Introductorio" cuyo "objetivo" es preparar al estudiante en las habilidades requeridas para enfrentar con éxito sus futuros estudios.

En el primer semestre de la carrera se utiliza metodología más activa. Los cursos están organizados en base a trabajo grupal y situaciones ABP. Se inicia con trabajo en equipo desde el primer día de clases, se forman grupos de cuatro estudiantes, que trabajaran juntos, durante todo el semestre. Las sesiones se desarrollan en base a actividades pre-elaboradas, en general guiadas, de diverso tipo; conceptuales, aplicativas y evaluativas, todas ellas abarcan competencias transversales. Paralelamente, se desarrolla durante el semestre un problema tipo ABP, donde los estudiantes toman decisiones en base a criterios específicos y que contemplan soluciones abiertas. Durante el transcurso se pueden realizar lecturas individuales, mapas conceptuales, tándem, rompecabezas, blogs, intercambio de roles, portafolios, debates, técnica de los seis sombreros, etc. Durante las sesiones de clase, el docente y los asistentes de cátedra, prestan permanente apoyo, manteniendo abierta la comunicación con los estudiantes. El objetivo es enseñar a "aprender a aprender", usando como detonante el curso y sus contenidos.

Por tanto, se utiliza una metodología hibrida, donde por cada sesión de dos horas, hay breves momentos de exposición, nunca mayor a 15 minutos, y aclaración pública del docente, sobre todo cuando se aprecia que hay dudas comunes, pero fundamentalmente se realiza trabajo grupal, donde se contempla la interdependencia positiva y la responsabilidad, tanto individual como grupal, de los miembros del equipo.

Respecto al problema ABP se les propone un cronograma (guía). Ellos deciden de qué manera van a hacerlo. Todo es negociable; dependiendo de la dificultad de las tareas, las fechas pueden ser cambiadas, se hacen las adaptaciones necesarias en el camino. Son los estudiantes los que seleccionan el material que requieren, donde lo consiguen y qué tratamiento van a darle. Por supuesto, también son responsables de la forma en que se organizan y la distribución del tiempo individual, ellos deciden sus estrategias.

3 Como entendemos la evaluación

Un proceso continuo, riguroso y sistemático, incorporada al proceso enseñanza-aprendizaje, que permite recoger información significativa para conocer la situación y tomar decisiones con la finalidad de mejorar progresivamente los aprendizajes, tal como lo indica (Ruiz, R (2011):

> *"La evaluación continua, por tanto, en el contexto actual, es una valoración integral, significativa, acumulativa que puede mostrar enormes ventajas para todas las partes que configuran el proceso de enseñanza-aprendizaje. Los alumnos reciben información sobre su ritmo de aprendizaje, pudiendo modificar métodos y hábitos, sobre cómo se les va a evaluar de una forma práctica, reorientando su aprendizaje si fuera necesario, y adquiriendo de forma paulatina los conocimientos y competencias que deben desarrollar en el estudio de una materia."*

Los procesos de evaluación cualitativa ofrecen información valiosa del avance del estudiante. El uso de permanente retroalimentación lo enriquece, de modo de acercarse un poco más a la formación integral. La evaluación de ningún modo debe ser utilizada como herramienta de poder, sino más bien como un factor motivacional. Se evalúa para la formación integral de la persona, formación para la vida, no como herramienta de poder, sino como un proceso continuo, esto es, se busca una evaluación formadora.

3.1 ¿Evaluar por competencias?

Evaluar por competencias supone tomar en cuenta los contenidos conceptuales, procedimentales y actitudinales, y puesto que el ser humano es muy complejo, no se debe olvidar la parte emocional/afectiva. En consecuencia, se requieren distintos marcos de trabajo para integrar todas las áreas. Según Bolivar, citado por Cano (2008):

> *"La mejor forma de evaluar competencias es poner al sujeto ante una tarea compleja, para ver cómo consigue comprenderla y conseguir resolverla movilizando conocimientos. Los instrumentos de evaluación empleados no pueden limitarse a pruebas para ver el grado de dominio de contenidos u objetivos sino proponer unas situaciones complejas, pertenecientes a la familia de situaciones definida por la competencia, que necesitará por parte del alumno, asimismo, una producción compleja para resolver la situación, puesto que necesita conocimiento, actitudes, pensamiento meta cognitivo y estratégico"*
>
> *"Todas las competencias relevantes se complementan y definen un conjunto de necesidades formativas. El conocimiento de la materia es básico; no basta con tenerlo –saber-, sino que se debe ser competente en el mismo –hacer o saber hacer-. Esto implica actualizar los conocimientos y técnicas, así como también otros elementos que las condicionan, como los cambios sociales e institucionales en los que se desarrollan. Un segundo paso está en la medición del grado de adquisición de competencias. Existen diferencias entre "estar capacitado" para hacer algo y "ser capaz de" realizar las acciones adecuadas"* (Triadó, X. M, Aparicio-Chueca, P. y Elasri-Ejjaberi, A. (2013)

La evaluación vigente en las instituciones superiores es sumativa, los estudiantes reciben una calificación, que debería reflejar el logro establecido. En busca de la integración, en la búsqueda de competencia, hay aspectos que deben ser tomados en cuenta:

- *Metas y objetivos claros y públicos.* El estudiante debe conocer lo que se pretende que logre, por tanto los criterios deben ser conocidos y compartidos por los estudiantes. Por supuesto, el primero que debe tener claros los objetivos de aprendizaje es el docente y el siguiente paso, asegurarse que también son claros para los estudiantes.

- *Propiciar la participación activa del estudiante*. De modo que desarrolle mayor autonomía y reflexión crítica, que sean capaces de tomar conciencia, reconocer lo que les falta y comprender los procesos interiores que le permiten aprender.

  "Las técnicas de aprendizaje activo exigen que los alumnos tomen la responsabilidad de su propio aprendizaje, guiados y motivados por el profesor. Una idea importante es que el alumno necesita reconocer el esfuerzo como paso vital en el proceso de aprendizaje." (Pinto, 2008).
- *Uso de instrumentos y recursos favorables.* Utilizar diversos instrumentos evaluativos favorece las diferentes modalidades de aprendizaje. Pero, sin importar el recurso o instrumento que utilicemos, la mayor importancia recae sobre la retroalimentación (feedback), que da el verdadero valor a la evaluación. Así como lo afirma Gairín (2009):

  > "*La retroalimentación tiene la capacidad de influir en el aprendizaje, pero la simple entrega de un resultado no conduce necesariamente a una mejora. Aumentar los límites de la retroalimentación para que ésta promueva el aprendizaje complejo tiene consecuencias trascendentales para el desarrollo de los estudiantes y las potencialidades que cada uno tiene.*"

  En la evaluación formativa, la retroalimentación consiste en la información que el docente va suministrando. Esto es, proporcionar orientación acerca del proceso para acortar distancias entre el aprendizaje realizado y los objetivos planteados en determinado contexto. Implica dar una serie de oportunidades para ir cambiando el rumbo.

  > "*Sin embargo, esa potencialidad del feedback parece depender de determinadas condiciones, como por ejemplo ofrecerse en el momento adecuado durante el proceso de aprendizaje y no sólo al finalizar el mismo, o darse de manera precisa y con suficiente claridad para que los estudiantes puedan utilizarl*o (Gibbs y Simpson 2004; Nicol y Macfarlane-Dick, 2006)"

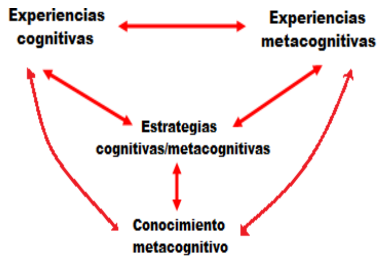
  Efectivamente, que ese feedback sea efectivo depende de estar disponible en el momento adecuado, no al finalizar cuando las conclusiones ya están establecidas. Al mismo tiempo ofrece un mayor nivel de motivación, compromiso con sus aprendizajes y desarrollo de competencias. Pero esta, no es responsabilidad exclusiva del docente, los estudiantes deben involucrarse y asumir la responsabilidad en la auto-regulación de su propio aprendizaje. "Un buen método para la obtención de información sobre el nivel de competencias de los titulados universitarios es su propia autoevaluación" (Conchado y Carot, 2010).
- *Comunicación efectiva docente-alumno*. Se requiere intercambio de pareceres, donde cada uno realice sus aportes. La motivación parte de la empatía, las interacciones en el aula, y fuera de ella, conllevan también un componente emocional/afectivo, necesario en cualquier situación interpersonal.
- *Recoger evidencias del desempeño.* Por último importa tanto el desempeño individual como el grupal. Al diseñar, tanto las actividades como el problema ABP, conectado con la realidad y dentro de su propio contexto permite que lo más importante no sea la apropiación de conocimientos y estrategias que adquiere el estudiante sino el uso que hace de ellos. Consecuentemente para establecer si un estudiante es competente o no toma se toma en cuenta las condiciones en las que se realiza el desempeño. (Martinez, 2009) señala al respecto:

  > "*La evaluación no puede promover el aprendizaje si se basa en tareas o preguntas que distraen la atención de los objetivos reales de la enseñanza. Históricamente, las pruebas tradicionales muchas veces orientaban la instrucción en una dirección equivocada, si centraban la atención en lo que es más fácil de medir, en vez de hacerlo en lo que es más importante de aprender*"

Precisamente esta tarea es la más difícil de implementar, cualquier herramienta o instrumento que se utilice resulta incompleto, lo cual hace necesario el uso de diversos medios para recoger los diferentes tipos de evidencias. La motivación resulta de la interacción entre el ambiente de aprendizaje y las características del estudiante. Resulta muy complejo determinar cuál de esos factores es más influyente, sin embargo, debemos recordar que el docente juega un rol importante como fuente de motivación en los alumnos, por tanto, debemos ser conscientes de los mensajes que transmitimos, tanto de manera directa como oculta.

Todos los factores son importantes: una organización de la clase que facilite la interacción, la estructura y secuencia de las actividades y ABP propuestos, los criterios públicos de evaluación, la adecuada retroalimentación y los documentos que le den estructura.

4 Competencia y metacognición



La decisión de trabajar en el aula, en base a trabajo cooperativo y situaciones ABP, responde a la necesidad de formar Ingenieros competentes. En consecuencia, las actividades y problemas ABP planteados representan la medula espinal de los cursos de Ciencias, y en este caso, específicamente de Química.

Pensar en las competencias que un estudiante debería adquirir en la universidad, supone reflexionar acerca de aquellas que aportan cada uno de los cursos durante sus estudios, por tanto, no olvidemos que la competencia se adquiere y se va formando. Debemos buscar la motivación al logro no a "evitar el fracaso". No olvidemos que la meta es el aprendizaje y el deseo de incrementar la competencia, no los resultados centrados en el juicio sobre su competencia y capacidad. Por tanto, los errores son naturales y útiles para mejorar y no un fallo. El fenómeno de la motivación es muy complejo, un enfoque simple resulta desde los motivos aprendidos, esto es el control, atribución y sentimiento de auto-eficacia.

Durante todo el proceso educativo se tienen permanentes situaciones de cognición-metacognición, conocimiento-estrategias, motivación-estrategias, etc. Todas ellas, están íntimamente relacionadas. Se requieren periodos de tiempo para interiorizar las experiencias, se trata de una evolución gradual en el proceso de aprendizaje.

La metacognición implica conocer cómo los logros obtenidos se basan en la propia actividad del estudiante, en cómo los conoce y cómo los controla. A mayor conocimiento metacognitivo, el aprendiz va ajustando sus expectativas de manera más realista y establece una imagen de sí mismo más positiva. Ya Biggs, en 1985 considero tres tipos de aprendizaje asociado a la motivación; *superficial* que aspira a superar la dificultad y evitar el fracaso, *profundo* donde el interés lo motiva a realizar el aprendizaje con estrategias significativas tratando de asociar contenidos nuevos y previos, *de logro* que independientemente del interés del material tiene como objetivo emplear estrategias organizadas para mejorar.

Trabajar en base a la solución de problemas reales favorece la motivación de los alumnos por el aprendizaje y, adicionalmente, hacia cuestiones adicionales de carácter interdisciplinar, incluyendo aspectos medioambientales y sociales. Es importante que el alumno se haga consciente de la actividad que desempeña, del control que pueda hacer de ella dependiendo de las características del contexto, su utilidad, la adaptación a los requisitos de una tarea, la forma de adecuarla a sus capacidades, así como, la forma en que controla su activación.

Es notable que, debido a la búsqueda y planteamiento de situaciones que puedan tener interés para el estudiante, el trabajo con metodología de este tipo también resulta motivante para el profesor y supone un reto que va enriqueciendo su rol.

5 Las mediciones

Puesto que se fomenta el aprendizaje activo y auto-aprendizaje, el alumno se ve involucrado en trabajo y seguimiento constante, que en cierta forma lo "obliga" a comprometerse con su aprendizaje. Recordemos que, como consecuencia de la masificación de las universidades, se nota una disminución en el compromiso del estudiante. Sin duda vivimos el efecto del aprendizaje social propiciado por el uso masivo de las tecnologías de información y la proliferación de aplicaciones para nuestra vida. A pesar de todas las ventajas que esto implica, no hay que perder de vista que se trata de cambiar la condición de app-dependientes por app-capacitados. En este contexto actual, la retroalimentación forma parte del proceso y resulta fundamental. Es claro que métodos de este tipo obligan a mejorar las formas de evaluación, que deben ser instrumentos de apoyo del proceso.

Cada semestre se ha venido realizado encuestas, entrevistas y conversaciones con alumnos que han llevado y aprobado los cursos de Química y de manera persistente se obtienen valoraciones positivas hacia este tipo de metodología, los porcentajes oscilan entre 80 y 85%. Los alumnos afirman que tanto las actividades como los problemas tipo ABP son de utilidad para asimilar conceptos e incrementan la motivación hacia la materia. Los estudiantes informan que los ayuda a adquirir confianza en lo aprendido y a trabajar mejor en equipo, al incrementar su capacidad de comunicación y tolerancia. Otro comentario recurrente es como, el uso de este método didáctico, permite encauzar los conocimientos y saber cómo utilizarlos.

La entrevista posterior a estudiantes que han sido promocionados permite percibir que la interacción social en combinación con la constante reflexión permite que se desarrolle la meta cognición. En conclusión, el ambiente de trabajo brinda mayor cantidad de oportunidades para su desarrollo. (Cañas, 2012)

Se ha iniciado la investigación cuantitativa con tres objetivos específicos:

- Evaluar las destrezas meta-cognitivas de estudiantes del primer año de Ciencias e Ingeniería durante la resolución de problemas.
- Correlacionar el desarrollo de la meta-cognición con la aplicación de metodología activa tipo ABP.
- Determinar la influencia de la retroalimentación en el desarrollo de la metacognición y el desempeño de los estudiantes.

5.1 La metacognición

En base al Inventario de Actividades Metacognitivas (MCAi) (Cooper-Sandi-Urena, 2009-2010) se ha elaborado un instrumento de 32 ítems que usa una escala tipo Likert de cinco niveles, explorando el uso de componentes reguladores de la meta-cognición (planeamiento, monitoreo y evaluación), donde un mayor uso de estrategias meta-cognitivas se asocia con valores altos de puntaje. El instrumento en las pruebas preliminares arrojo una confiabilidad expresada como alfa de Cronbach de 0,85 determinado en la aplicación piloto. El tiempo requerido para responder el test es entre 20 y 30 minutos. (Cañas, 2013)

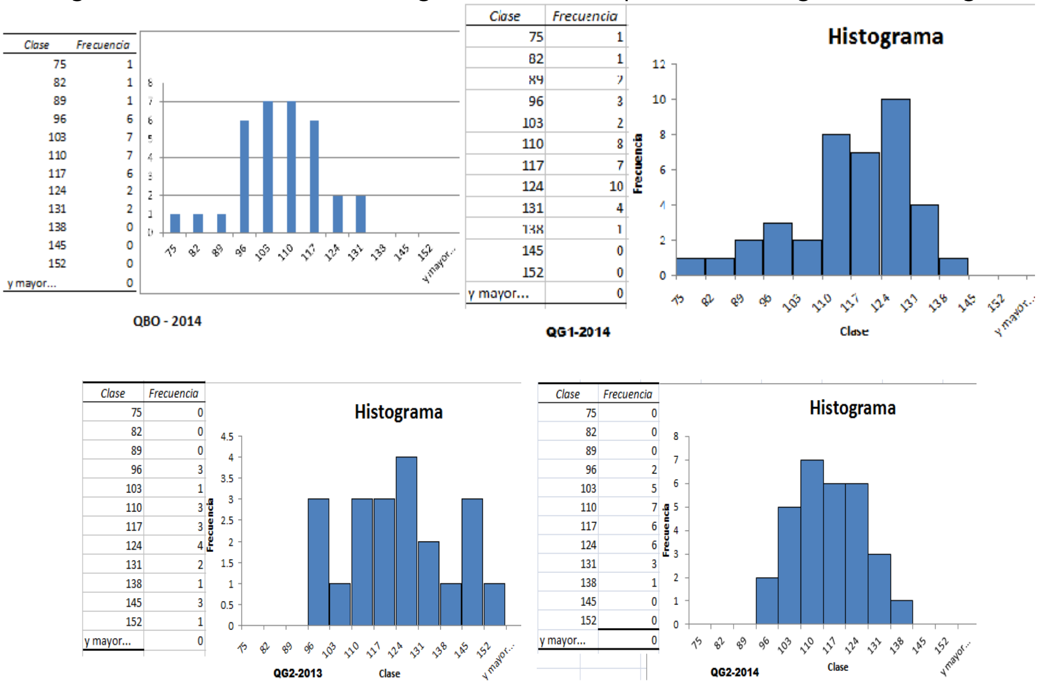
El test se ha venido aplicando durante estos semestres a estudiantes del primer y segundo año, se han reformulado algunas de las preguntas, se cuenta con 28 items, el coeficiente Cronbach 0,88 y se tiene un índice de correlación de Pearson 0,62. Los resultados del test se muestran en la tabla siguiente:

Tabla 1: Resultados de la aplicación del test.

Prueba	Puntaje máximo	Puntaje mínimo	Media	Desviación estándar	Mediana
Piloto	149	79	114	13,25	113
QBO-2014	126	66	105	13	100,5
QG1-2014	140	55	112	15,94	117,5
QG2-2013	146	94	118	16,5	116,5
QG2-2014	143	101	120	10,7	120

Los valores reportados de QBO corresponden a estudiantes recién salidos del curso propedéutico, futuros ingresantes al primer semestre. QG1-2014 corresponde a alumnos del 2014-I que han cursado un semestre en

la universidad. Los valores para QG2-2013 y QG2-2014 pertenecen a semestres 2013-II y 2014-II, son dos grupos diferentes de estudiantes, después de llevar el curso de Química con metodología hibrida y ABP.
Se ve claramente como los puntajes obtenidos en el test aumentan a medida que el estudiante avanza, sin embargo es más interesante observar como el puntaje mínimo cambia sustancialmente, un 39% (de 55 a 94) y 46% (de 55 a 101) esto sucede a pesar que la media se mantiene en rangos similares. Como sabemos, el estudiante motivado intrínsecamente, conoce sus habilidades y las emplea, por tanto, la importancia de este hecho radica más bien en como la aplicación de esta metodología hibrida permite que los estudiantes más rezagados mejoren su autoconocimiento de manera más acelerada. Esta situación persiste en ambas muestras después de la aplicación didáctica. La diferencia entre una y otra muestra en el mismo nivel (QG2), radica en que, a pesar que los puntajes obtenidos son muy semejantes, el segundo grupo (QG2-2014) es más homogéneo en habilidades metacognitivas. Esto se aprecia en los siguientes histogramas.



QBO - 2014

Clase	Frecuencia
75	1
82	1
89	1
96	6
103	7
110	7
117	6
124	2
131	2
138	0
145	0
152	0
y mayor...	0

QG1-2014

Clase	Frecuencia
75	1
82	1
89	2
96	3
103	2
110	8
117	7
124	10
131	4
138	1
145	0
152	0
y mayor...	0

QG2-2013

Clase	Frecuencia
75	0
82	0
89	0
96	3
103	1
110	3
117	3
124	4
131	2
138	1
145	3
152	1
y mayor...	0

QG2-2014

Clase	Frecuencia
75	0
82	0
89	0
96	2
103	5
110	7
117	6
124	6
131	3
138	1
145	0
152	0
y mayor...	0

Figura 1: Histogramas

Estos resultados llevaron a preguntarse ¿y si hay más retroalimentación de calidad habrá mejores resultados? Con el objeto de medir qué tanto, se han utilizado diferentes rúbricas de evaluación para el mismo grupo de estudiantes.

5.2 La influencia de la retroalimentación

Dentro de los problemas ABP se considera tantas etapas como evaluaciones programe la secretaria académica. Estas etapas tienen relación con las unidades del curso. En QG2-2014 se planteó de diferente manera la evaluación de los alumnos; las dos primeras etapas se utilizó una rúbrica general, donde se indicaban criterios con un lenguaje muy general. El grupo de estudiantes debía plantear y entregar su solución al problema en una fecha determinada.
En las siguientes etapas, se planteó la situación de diferente manera, se consideraron entregas parciales y se insistió en reuniones con el grupo para intercambio de opciones, opiniones, etc.

Aún sin tener "obligación" de presentar avances ni recibir retroalimentación hay grupos que voluntariamente la buscan, comparan información, extraen ideas, plantean soluciones, muestran y buscan orientación, hacen propuestas y verifican sus planteamientos. La mayor parte de grupos simplemente resuelve el problema de la manera que mejor le parece y hace consultas ocasionales, unos pocos solo cumplen con entregar sin mucha preocupación por lo que presentan.

Sucedió lo siguiente: Los grupos que voluntariamente buscan retroalimentación siguieron haciéndolo, la mayor parte, que consultaba ocasionalmente incremento el freeback y sus resultados aumentaron en calidad, de los pocos que no buscan retroalimentación, una fracción la busco, de forma que también incrementaron su calidad. Es decir, disminuyo notablemente la brecha inicial entre los diversos grupos. Los resultados se presentan a continuación:

Tabla 2: Puntajes obtenidos en las etapas del problema ABP

Grupo	Etapa 1 (sin feedback)	Etapa 2 (sin feedback)	Etapa 3 (con feedback)	Etapa 4 (con feedback)
Grupo1	0,25	0,75	2,25	2,75
Grupo 2	3	3	3	3
Grupo 3	1,5	1,5	2,25	2,5
Grupo 4	1,75	2	2,75	3
Grupo 5	2.5	2,5	3	3
Grupo 6	2	2,25	3	3
Grupo 7	2,25	2	2,5	2,75
Grupo 8	1,5	1,75	2	1,75
Grupo 9	1,5	1,75	2,5	2,75

Puntaje total: 3 puntos
Grupo 2: Siempre busco retroalimentación, ya sea considerada o no en la rúbrica.
Grupo 8: Permanecieron sin retroalimentación

Se aprecia el cambio cuando se utiliza una rúbrica general y una rúbrica con diversas oportunidades de revisión para la toma de decisiones, la mejora de calidad del trabajo del mismo grupo con y sin retroalimentación es evidente.

Recordemos que en el problema ABP Tanto el proceso, como la solución (resultado, producto entregado) forman parte de la evaluación. Este es el grupo cuyas habilidades metacognitivas resultaron más homogéneas.

6 Conclusiones y recomendaciones

La masificación, de las universidades, constituye un fenómeno evidente y es causa de los mayores impactos a nivel de enseñanza universitaria. Consecuencia de ello, llegan a la universidad estudiantes cada vez más diversos en cuanto a expectativas, recursos económicos, etnia, edad, capacidad intelectual, motivación, etc. Otra consecuencia de la masificación es el control social de la universidad, lo que decanta en control de calidad de las instituciones. Las exigencias, cada vez más cambiantes, obligan que la planificación y praxis educativa, sean permanentemente revisadas y analizadas a fin de permitir superar las dificultades y posibilitar mejores alternativas tanto para alumnos como instituciones.

En las carreras de Ingeniería, los primeros cursos corresponden a ciencias básicas. Puesto que son obligatorios, y tomando en cuenta que el proceso educativo es básicamente un proceso de comunicación social y adaptativo, proporcionan un espacio invaluable para emplear medios y metodologías adecuadas para un real acercamiento a la ciencia y su potencial, así como ayudar en la formación integral de los estudiantes. Dada esta realidad:

- Las competencias requeridas a los docentes se han modificado. El éxito en el aprendizaje de la ciencia se relaciona al interés que puede despertarse en los estudiantes, por tanto, el conocimiento de los aspectos elementales involucrados en el proceso educativo se hace indispensable. Esta situación es la razón por la cual la preparación de los docentes que se desempeñan en los primeros años es determinante. El profesor debe capacitarse para distinguir en cada estudiante la gradación y ser capaz de “emitir juicios” sobre el nivel con que éste pone en práctica los conocimientos.
- La evaluación en base a competencias presenta dificultades y limitaciones, sobre todo cuando se trabaja con los primeros años de pregrado, donde se debe incentivar la motivación de los estudiantes.

Por tanto la actitud del docente es básica ya que se contagia a sus estudiantes, recordemos que se trata de vasos comunicantes que se motivan mutuamente.

- Esta experiencia muestra que, a pesar del acceso ilimitado a la información, la generación app, tiene problemas para analizarla críticamente y la retroalimentación se hace necesaria, especialmente en los primeros años de carrera.
- Se muestra, de manera cualitativa y cuantitativa, la influencia del modo de acercamiento, en particular metodología híbrida y ABP. Sin embargo, la evaluación de cualquier constructo debe realizarse desde diferentes propuestas, se ha analizado el factor desarrollo de la metacognición y retroalimentación para mejorar los aprendizajes, no obstante, hay otros factores, susceptibles de analizar, que pueden co-ayudar y que no se están tomando en cuenta, tales como el incremento de la madurez, la relación emocional docente-estudiante, el grupo específico de trabajo, etc. Se requieren diferentes instrumentos de evaluación para corroborar estos factores. Esta metodología ayuda a valorar no solo el nivel de conocimientos alcanzado, también los elementos que intervienen en ser "competente" que suponen el conocimiento de la materia, pero hay que saberla aplicar.
- Las posibilidades de éxito de los estudiantes mejoran cuando comienzan con una visión de hacia dónde se dirigen. Las rúbricas y la retroalimentación ayudan en esa dirección, los resultados son alentadores tanto por los porcentajes % obtenidos, pero, no se puede olvidar que cualquier propuesta que se aplique requiere adaptarla al contexto y medición buscada.

Es difícil generalizar los resultados más allá de la propia institución, corresponde a una muestra y contexto especifico, aun así, hace posible la indagación en otros contextos y materias. La finalidad es determinar la incidencia en determinados ambientes de trabajo y en los niveles iniciales del proceso formativo y poder extenderlos hacia otras promociones e intuiciones.

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Social Entrepreneurship Projects: a Context to Educate Engineers Aware of Themselves and the World

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Abstract

The "Industrial Engineering Workshop I" is a mandatory and introductory course for the Industrial Civil Engineering career at the University of Chile. Initiated in 1997 this course has had a permanent evolution, being today centered in Self Awareness as main pedagogical objective and Social Entrepreneurship Projects as the main methodological resource. The long experience with the course, centered in the non-cognitive learning dimensions, has allowed the teaching team to observe a significant impact in terms of generating consciousness, openness and enthusiasm in students about new learning paradigms and the increasing importance of "soft skills". Last four years, Social Entrepreneurship Projects have been introduced as the central learning context, all other activities of the course being connected to them. This has produced a significant contribution to student's motivation, towards their studies and their lives in general. The use of a Radical Constructivist paradigm, as a philosophical basis for the course, has been of great help to increase student's awareness and ambition to produce significant transformations in themselves and in the world around them. Becoming aware that learning is not so much about "Knowing Oneself" as it is about "Inventing Oneself", making sense of the "Engineering of Self" concept, is a clear contribution for students to transform their studies in an integral process of formation as professionals, citizens and persons. The course has also had a significant impact on the communities in which students have developed their Social Entrepreneurship Projects.

Keywords: Awareness; Social Entrepreneurship Projects; Radical Constructivist; Pedagogical paradigms

Proyectos de Emprendimiento Social: un Contexto para Educar Ingenieros Conscientes de si mismos y del Mundo.

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Abstract

El "Taller de Ingeniería Industrial I" es un curso introductorio y obligatorio en el plan de estudios de los Ingenieros Civiles Industriales de la Universidad de Chile. Iniciado en 1997, este curso ha tenido una continua evolución, estando en la actualidad centrado en la Expansión de Conciencia de Sí como objetivo central y en el diseño, realización y evaluación de Proyectos de Emprendimiento Sociales (PES) como principal recurso metodológico. La larga experiencia del curso, centrado en las dimensiones no cognitivas del aprendizaje, ha permitido al equipo docente constatar un impacto significativo en términos de generar en los estudiantes conciencia, apertura y entusiasmo en relación a nuevos paradigmas de aprendizaje, así como en relación a la importancia de las "habilidades blandas". En los últimos cuatro años, Proyectos de Emprendimiento Social han sido incorporados como contexto central de aprendizaje, con todas las otras actividades del curso conectadas con ellos. Esto ha producido una significativa contribución a incrementar la motivación de los estudiantes, hacia sus estudios y hacia la vida en general. El desarrollar el curso en una plataforma Constructivista Radical ha permitido, además, incrementar significativamente la conciencia y la ambición de los estudiantes en relación a la posibilidad de producir transformaciones significativas en el Mundo y en Sí-mismos, no sólo como futuros profesionales sino también en su condición de estudiantes. Que los estudiantes tomen conciencia de que no se trata tanto de "Conocerse a Sí-mismos" como de "Inventarse a Sí-mismos", dando sentido al concepto de "Ingeniería del Sí-mismo", ha sido una clara contribución a que los estudiantes transformen sus estudios en un proceso integral de formación como profesionales, ciudadanos y personas. El curso ha tenido también un significativo impacto en las comunidades en las cuales los estudiantes han llevado adelante sus Proyectos de Emprendimiento Social.

Keywords: Expansión de Conciencia; Proyectos de Emprendimientos Social; Constructivismo Radical; Paradigmas Pedagógicos

1 Introducción

La necesidad de innovar en la Educación en Ingeniería es hoy un imperativo que nadie niega. Algunos lo enuncian como una revolución urgente (Goldberg, Somerville, 2014).

Ello responde tanto a los cambios ónticos, las "Nuevas Realidades" que anunciaba tempranamente Drucker (1989), como a los cambios ontológicos, los nuevos paradigmas que buscan dar sentido y generar nuevas posibilidades y necesidades a partir de esas nuevas realidades (Vignolo, 2001).

En el Departamento de Ingeniería Industrial (DII), parte de la Escuela de Ingeniería y Ciencias de la Universidad de Chile, cambios paradigmáticos y pedagógicos empezaron a ser introducidos en la formación de los Ingenieros Civiles Industriales (ICI´s) a partir de 1986, fruto de un diálogo iniciado ese año entre un grupo de académicos del DII y el Laboratorio de Epistemología Experimental de la Facultad de Ciencias de la misma universidad, dirigido en ese momento por Humberto Maturana, destacado biólogo chileno que obtuviera el Premio Nacional de Ciencias de Chile el año 1994.

Diez años antes de la emergencia del paradigma de la Inteligencia Emocional, las componentes no cognitivos de la educación empezaron a ser incorporadas en algunos cursos del DII. Adicionalmente, nuevos cursos electivos fueron creados a partir de ese encuentro de disciplinas, normalmente muy distantes entre sí.

El "Taller de Ingeniería Industrial I" (IN3001) es el primer curso obligatorio de la carrera de Ingeniería Civil Industrial generado a partir de esta línea de innovación educativa. En la actualidad es impartido en el primer semestre de esta especialidad, el quinto semestre de la carrera, de 12 semestres de duración.

Iniciado en 1997, este curso ha tenido una continua evolución, estando hoy en día centrado en la Expansión de Conciencia de Sí como objetivo central y en el diseño, realización y evaluación de Proyectos de Emprendimiento Sociales (PES) como principal recurso metodológico.

El Taller IN3001 ha impactado el diseño curricular y pedagógico de Ingeniería Civil Industrial y, crecientemente, el de la Escuela de Ingeniería en general. A la presentación final de los PES asisten autoridades y profesores de la Escuela de Ingeniería, que valoran cada vez más el desarrollo de las antes denominadas y no muy valoradas "Habilidades Blandas".

El presente artículo expone el marco filosófico, el modelo pedagógico del curso y los principales resultados y conclusiones obtenidos del mismo.

2 Objetivos del Curso

El programa oficial del Curso IN3001 "Taller de Ingeniería Industrial I" enuncia sus objetivos de la siguiente manera:

"Al término del curso, el alumno que haya realizado rigurosamente todas las actividades que se le soliciten:

1. *Tendrá un incrementado nivel de conciencia de sí, en lo relativo a sus intereses y propósitos personales y profesionales así como en los ámbitos en que desea desarrollar capacidades distintivas y trascender como profesional.*
2. *Conocerá estrategias para desarrollar actitudes e incrementar habilidades en los ámbitos de: aprender, escuchar empático, coordinarse a través del diseño y la gestión de compromisos, comunicarse por escrito y verbalmente, construir confianza, trabajar en comunidad/equipo, presentar, liderar, observar y modular sus estados de ánimo, lectura y aprovechamiento de textos y, dependiendo del involucramiento en el curso y los roles que juegue, habrá incrementado algunas de dichas habilidades.*
3. *Será consciente de la crucial importancia del respeto y cultivo de principios y valores en el desempeño profesional y habrá incrementado su capacidad para evaluar y tomar decisiones éticas cuando enfrente situaciones características de su vida como estudiante universitario primero e ingeniero posteriormente.*
4. *Conocerá y comprenderá los ámbitos de acción del Ingeniero Civil Industrial y las áreas de investigación del Departamento de Ingeniería Industrial de la Universidad de Chile, siendo capaz de adoptar decisiones fundamentadas acerca de sus opciones de especialización durante sus estudios y para su posterior carrera profesional."*

3 Marco Conceptual

El curso ha sido diseñado a partir de un Modelo Teórico Constructivista doblemente Radical (CRR) -epistemológico y ontológico (Vignolo, 2012)- basado en la Biología del Conocimiento propuesta por Humberto Maturana y Francisco Varela (Maturana y Varela, 1992). En éste modelo, el estudiante no sólo diseña y gestiona su programa y proceso de aprendizaje sino también se diseña y construye a Sí-mismo, como un ser humano único, preparado para vivir la vida de una forma contingente a sus particulares intereses, aspiraciones y capacidades, ambos componentes también susceptibles de ser diseñados. A esto es lo que nos hemos referido como la Ingeniería del Sí-mismo (Vignolo, Celis, 2010).

Adicionalmente, en el modelo CRR los seres humanos nunca podemos saber como la "realidad" es. Sólo podemos saber como la vemos, dados nuestros particulares paradigmas, focos atencionales y estados de ánimo. Estos tres factores son modificables, siéndonos, posible cambiar la realidad en que vivimos a través de la modulación de una o varias de estas variables.

En el curso se busca, como plataforma teórica básica, que los alumnos tomen conciencia de las posibilidades que esta opción filosófica les abre en la construcción del aprendizaje, el Sí-mismo y la realidad en que viven, incluyendo el contexto educacional en que están participando. "Tomar Conciencia" es entendido en este marco conceptual como un proceso de reconfiguración de la estructura de la persona – especialmente de su sistema nervioso- con foco en los aspectos actitudinales, emocionales y espirituales.

El curso se organiza en torno a la expansión de conciencia relativa a:

1. La crucial importancia de la conciencia en la construcción de Sí y del Mundo.
2. La incidencia de las emociones y del cuerpo en esos mismos procesos.
3. El rol de los paradigmas en la construcción de la realidad, externa e interna.
4. El rol de las Pasiones, Competencias Distintivas y Afanes de Trascendencia en la invención del Sí-mismo.
5. El fenómeno del trabajo y del rol constitutivo de los compromisos en la vida humana en sociedad.
6. El rol del aprender, como proceso genérico, en la construcción del Sí-mismo como persona así como del aprendizaje de las teorías y metodologías propias de la Ingeniería Industrial en la construcción del Sí-mismo en cuanto profesional.
7. Los elementos centrales de la cultura y la realidad social del entorno en que vive.
8. El poder de las conversaciones –entendidas como transformación en la convivencia- en la construcción social de la realidad.

Emprender es conceptualizado y ofrecido a los alumnos del curso como una "Actitud Vital": "Hacerse cargo de algo que a uno le importa, tomando acción al respecto". Se propone el emprender como elemento constitutivo del fenómeno evolutivo que da origen a la especie humana. Valido en todos los ámbitos de la vida humana, incluyendo el aprender, que es presentado como el emprendimiento primordial, base de todos los otros emprendimientos. Ello da origen a uno de los mantras del curso: "Learning to Start Starting by Learning" (Vignolo, Celis, 2008).

Innovar es conceptualizado y ofrecido a los estudiantes como la evolución "Darwiniana" en el espacio de la autoconciencia humana, que corresponde a la conceptualización "Lamarkiana" de evolución, en la cual la especie humana, a diferencia de todos sus predecesores, no sólo se adapta a los cambios del entorno sino que, además, modifica conscientemente el entorno para producir una deriva evolutiva deseada.

Otro concepto clave del modelo es "Quiebre", entendido como aquello que separa la situación vivida de la situación deseada. "Quiebre" es aquello que falta o que sobra para que ocurra el estado de "transparencia", aquel en el que devenir de un sistema no requiere ni de conciencia ni de decisión ni de esfuerzo humano.

Los "Quiebres" juegan un rol central en la toma de conciencia, precisamente porque "quiebran" una transparencia que era o impiden alcanzar una transparencia que nunca fue. El curso está diseñado de tal manera de procurar generar "Quiebres" que produzcan en los estudiantes las expansiones de conciencia en los ámbitos deseados.

La distinción "Quiebre" permite, además, cimentar una interpretación del diseño y la innovación que se aleja del paradigma de la "Resolución de Problemas", que ha jugado un rol central en la tradición de la ingeniería. Siguiendo el trabajo seminal y pionero de Flores y Winograd (1986), se propone a los estudiantes una visión de los "Quiebres" como apertura de nuevas posibilidades para innovar , con potencial para generar nuevo valor, no sólo para quien experimenta el "Quiebre" sino para todos aquellos que experimentan situaciones de esa naturaleza. Ello involucra un cambio radical en la actitud, estado de ánimo y dimensión temporal y espacial en que se vive el "Quiebre".

Es por ello que otro aspecto crucial del curso, es la observación y modulación de los estados de ánimo así como el manejo de la temporalidad.

El concepto de paradigma, tal como fuera propuesto por Kuhn (1962), juega un rol también un central en el curso. Se invita a los estudiantes a investigar los paradigmas de la cultura en que viven y, a partir de allí, los paradigmas principales que en ellos viven y desde los cuales construyen la realidad en que viven. El curso muestra también la posibilidad de expandir el espacio de libertad personal y las posibilidades de ser y hacer, por la vía de hacer cambios en los paradigmas en que se vive.

4 Modelo Pedagógico

Para alcanzar los objetivos del curso, el marco conceptual constructivista expuesto se operacionaliza en el siguiente modelo pedagógico:

- Se invita a los estudiantes desde el inicio del curso a "apropiarse" del proceso de diseño y gestión de su programa de aprendizaje en el curso. Se les expone tempranamente el modelo pedagógico, con énfasis en el carácter no cognitivo del "No-Curso", denominación que se usa recurrentemente para instalar este carácter del curso en la conciencia de los alumnos.
- La responsabilidad principal del equipo docente es diseñar y gestionar un "Contexto de Aprendizaje" -concebido y expuesto a los estudiantes como un "Gimnasio" o "Campo de Prácticas"- en los cuales ellos llevan adelante su Programa de Aprendizaje.
- El componente central de este "Contexto de Aprendizaje" son los PES, que los lleva rápidamente a "Ir a la Calle", a experienciar la "realidad" social y la cultura en que viven, especialmente aquella de los segmentos marginados, rezagados y vulnerables del entorno social: Hogares de Ancianos, Colegios Públicos Vulnerables, Cárceles, Barrios Pobres, Grupos de Cesantes, entre otros.
- El equipo docente conforma al azar Comunidades de Aprendizaje (CA) grandes (entre 20 y 25), para asegurar que enfrenten dificultades significativas de coordinación así como la necesidad de generar sub grupos especializados en distintas funciones. El desempeño de algunas de estas funciones les generan "Quiebres" de los cuales se hacen cargo las disciplinas que participan en la formación de los Ingenieros Industriales: Gestión de Personas, Marketing, Gestión de Operaciones, entre otras. Al constituir las CA se procura garantizar diversidad de género y rendimiento académico.
- Los PES son varios y en paralelo (Habitualmente 4 por CA), complejos, muy poco estructurados al serles sugeridos al inicio del curso y con alta probabilidad de generar muchos y variados quiebres, incluyendo la posibilidad del total fracaso de algunos de ellos. (Normalmente se les pone a disposición un conjunto de 80 alternativas de proyectos, pero los estudiantes pueden incluir otros proyectos generados por ellos dentro del portfolio de emprendimientos sociales de cada grupo).
- No obstante los proyectos sugeridos son muy poco estructurados, con muchas complejidades e incertidumbres, se les pide que el proceso de trabajo sí siga una estructura rigurosa: mantener una ruta crítica actualizada, realizar reuniones semanales de evaluación del avance del proyecto (con especial énfasis en la identificación de "Quiebres") y elaborar reportes de avances semanales (con foco en el rediseño del plan de trabajo y la organización del equipo, a partir de los "Quiebres").
- Una práctica a la que se le concede especial importante es a la Co-evaluación de Desempeño de los estudiantes, dentro de su grupo de trabajo. Estas co-evaluaciones son incluidas en las presentaciones de avance plenarias, frente a la totalidad de los alumnos del curso y del equipo docente (alrededor de 150 personas). Con esta práctica se busca generar conciencia del rol central del evaluar en el funcionamiento de los equipos, respecto a lo cual hay muy poca conciencia y pobres competencias en la cultura chilena.
- Cada CA es acompañado, en la realización de sus PES, por tres "Learning Assistant", nombre que explícita el carácter no instruccional de parte de los estudiantes de niveles superiores que cumplen esta función.
- Cada semana se realizan talleres de Desarrollo de Distinciones de Proyectos (Ontología del Curso) y Expansión de Conciencia, de tres horas de duración, donde se invita a los alumnos a reportar lo que está pasando con ellos en el curso. A partir de estos reportes se desarrollan las principales distinciones del curso: – "Conciencia", "Conversar", "Quiebres", "Emprender", "Innovar", "Estados de Animo", "Redes de Ayuda", "Ciclo del Trabajo", Ontología de los Compromisos", "Paradigmas", "Obscuchar", entre

otras. Todas ellas son aportadas a los estudiantes como forma de reconstruir las situaciones vividas en los PES, en función de aprender de ellas, especialmente en relación a las expansiones de conciencia buscadas.

- Adicionalmente, en estos talleres se realizan ejercicios para entrenar el observar y modular estados de ánimo, preguntar, autoevaluarse en el ámbito del emprender e identificar paradigmas, pasiones y afanes de trascendencia.

5 Resultados

Al término del curso y de los PES, cada CA realiza una evaluación del impacto de cada uno de los PES realizados. A su vez, cada alumno evalúa el impacto del curso en su vida como estudiante y en otros ámbitos.

En su conjunto, los alumnos de cada versión impactan en promedio, de diversas maneras y con distintas intensidades, a miles de personas de forma directa.

Para financiar la realización de los PES, para los cuales no cuentan con financiamiento alguno provisto por el curso, en la última versión generaron ingresos por aproximadamente US$ 70.000. Algunos de los proyectos han aparecido en televisión abierta.

Durante los últimos cuatro años, los estudiantes han realizado sesenta y cuatro PES, ocho de ellos con impacto nacional. Cuatro de ellos han continuado más allá del término del curso.

Entre los PES destacan, por el impacto en las comunidades involucradas:

1. “Volviendo a Sonreír”: los estudiantes realizaron visitas periódicas por 10 semanas a un hospital para cumplir el sueño de 30 niños con enfermedades terminales.
2. “Navidad Solidaria”: el proyecto logró un día de juegos y celebración de la navidad para 300 niños junto a sus madres en una cárcel.
3. “Feria Laboral”: los estudiantes lograron que 35 compañías ofrecieran 2,600 empleos para adultos mayores.
4. Jornadas Anti-bullying: Los estudiantes implementaron jornadas en 12 colegios de 5 regiones distintas de Chile.
5. Los estudiantes produjeron tres Documentales sobre la realidad de la educación en colegios vulnerables y el abuso de fármacos en niños con déficit atencional, con más de 20.000 visitas en Youtube en su conjunto.
6. Instalación de paneles termo-solares y sistemas de reciclaje orgánico en 4 escuelas rurales.

Los principales impactos declarados por los estudiantes como resultado de su participación en el curso se resumen en la Tabla 1:

Tabla 1: Impactos del curso en los estudiantes

Principales Impactos del Curso en los Estudiantes	%
Tomar Conciencia de mis Debilidades y Competencias	23%
Incremento de la motivación por la carrera y el aprendizaje	21%
Tomar Conciencia en la práctica de lo que es trabajar y trabajar en equipo	21%
Desarrollo de Habilidades	18%
Capacidad de Convertir Quiebres en Oportunidades	17%

Algunas frases literales declaradas por los estudiantes, que reflejan lo que muchos otros declaran a través de enunciados similares, son:

"…Me ayudó muchísimo a darme cuenta de las cosas que puedo lograr."

"…Siento que entendí y viví lo que significa trabajo en equipo y como organizar los trabajos…"

"…Después de este curso tengo nuevos sueños y mayor conciencia de que hay que disfrutar las cosas durante el proceso y no al final del camino".

"…Me di cuenta de las habilidades que tengo más desarrolladas así como las que no, y como aprender a trabajar sobre éstas, para sacar el máximo provecho…"

"…Me cambió la perspectiva sobre muchas cosas, y me hizo reflexionar sobre temas que jamás me había cuestionado."

Al término del semestre luego de la presentación final, familiares de los estudiantes y beneficiarios de los proyectos han compartido sus comentarios con el equipo docente, a través de expresiones como las siguientes:

"…Felicitaciones por las iniciativas que están implementando y, sobretodo, por permitir que jóvenes universitarios amplíen su mirada a la realidad y se involucren apasionadamente (y con rigor ingenieril), con el mundo que los rodea" (Papá de Estudiante).

"Fue un honor trabajar junto a los estudiantes del Departamento de Ingeniería Industrial. Les agradezco enormemente la oportunidad y felicito a todos los que estuvieron en el día a día" - Director Ejecutivo de Fundación Enseña Chile.

"Es un modelo de enseñanza que en nuestros planes de estudio deberíamos incorporar con más fuerza"
Decano Facultad Ciencias Físicas y Matemáticas.

6 Conclusiones y Discusión

La experiencia del curso, en sus ya 18 versiones centradas en las dimensiones no cognitivas del aprendizaje, nos ha permitido constatar el impacto de este tipo de cursos en la apertura de los estudiantes hacia nuevos paradigmas de aprendizaje así como el aporte al aprendizaje en el ámbito de las habilidades profesionales.

La experiencia de los últimos 4 años nos ha permitido, adicionalmente, constatar el gran aporte de los Proyectos de Emprendimientos Sociales a la expansión de conciencia de Sí y de mundo de los estudiantes, así como el aumento de la motivación, hacia sus estudios y hacia la vida en general.

El desarrollar el curso en una plataforma Constructivista Radical ha permitido, además, incrementar significativamente la conciencia y la ambición de los estudiantes en relación a la posibilidad de producir transformaciones significativas en el Mundo y en Sí-mismos, no sólo como futuros profesionales sino también en su condición de estudiantes.

Que los estudiantes tomen conciencia de que no se trata tanto de "Conocerse a Sí-mismos" como de "Inventarse a Sí-mismos" cambia fuertemente el sentido de ser aprendices e incrementa fuertemente la motivación hacia el estudio y la transformación de Sí-mismos, en la interacción con los miembros de su Comunidad de Aprendizaje, el equipo docente y las comunidades externas a las cuales buscan impactar positivamente con sus PES.

La realización de los PES contribuye, además, a generar conciencia de que la "realidad" no está "Allá Afuera", determinada como contexto inmodificable para ellos sino que, por el contrario, es susceptible de ser significativamente mejorada, siendo ello el sentido último del ser profesional, del emprender y el innovar.

La constatación del poder de los equipos de trabajo, las redes sociales – presenciales y virtuales- y las conversaciones – como trasformación en la convivencia- es otro ámbito de aprendizaje transformacional para los alumnos.

Uno de los desafíos para futuras versiones del curso es hacerse cargo del grupo de alumnos que no logran alcanzar un umbral de apertura y motivación tal que les permita disfrutar y obtener aprendizajes significativos, durante el curso. Algunos de ellos resienten que este paradigma de aprendizaje se les presente en el 5º Semestre, habiendo hecho un gran esfuerzo para adaptarse al paradigma fuertemente cognocitivista y cientificista del Plan Común de Ingeniería, que les toma los 4 primeros semestres. Una opción obvia al respecto es dictar el curso en el primer semestre, aprovechando el estado de ánimo de apertura a lo nuevo de quienes recién inician estudios superiores.

Un tema relevante para futuras evaluaciones, rediseños y presentaciones del curso es el relativo a la transformación que experimenta el equipo docente durante cada nueva versión del curso, que es sin duda alguna muy significativo también.

El planteamiento básico que se propone a los estudiantes durante todo el curso, es que la razón de ser de los Proyectos de Emprendimiento Social, es que cada alumno sea capaz de "Hacerlo Bien, Pasarlo Bien y Hacer el Bien". Es decir, alcanzar un elevado rendimiento y resultados, disfrutar de su proceso de aprendizaje y ayudar a otros, especialmente a sus compañeros y beneficiarios de los proyectos, a alcanzar estos logros.

Finalmente, ayuda significativamente a lograr los objetivos del curso presentar la educación superior como un proceso cuyos objetivos fundamentales, por sobre la capacitación profesional, es la formación de personas con sólidos valores y actitudes humanistas, ciudadanos democráticos, libertarios, solidarios, concientes y responsables de su compromiso con el mejoramiento de la vida en sociedad.

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The Development of the Entrepreneurial Culture

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Abstract

The analysis of the entrepreneurship behavior has focused on personality traits and in the analysis of motivation. Today, scientific literature agrees that a) the need for achievement, b) the need for power and c) the need for affiliation, are three key dimensions associated with entrepreneurship behavior. In this context, cognitive variables examined in the literature show that d) locus of control, e) perseverance, f) risk perception and g) creativity are fundamental dimensions to the promotion of entrepreneurship. Thus, the aim of this study was twofold. First, we intended to examine the extent to which these competencies were present in university students and, secondly, after implementing a program based on Project-based Learning (PBL) we looked at the level of change of such competencies.

399 participants enrolled in university and aged between 18 and 31 years (Mage = 22.04, SD = 4.07) took part in a quasi-experimental study with a non equivalent control group. The results indicated that the experimental group showed higher values in various of the competencies examined. Conclusions of the study deepen the importance of attitudes and skills associated with the entrepreneurship behavior and in the usefulness of intervention programs for promoting entrepreneurship in university students.

Keywords: Entrepreneurship; Intervention program; Project-based learning (PBL) , Development of socio-emotional skills

Desarrollo de la Cultura Emprendedora

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Abstract

El análisis del comportamiento de la persona emprendedora ha centrado su atención en los rasgos de personalidad y en el análisis de la motivación. Así, hoy en día, la literatura comparte que, a) la necesidad de logro, b) la necesidad de poder y c) la necesidad de afiliación, son tres dimensiones fundamentales asociadas a la conducta de toda persona emprendedora. En este ámbito, las variables cognitivas examinadas en la literatura demuestran que, d) el locus de control, e) la perseverancia, f) la percepción del riesgo y g) la creatividad, constituyen dimensiones fundamentales para el fomento del emprendimiento. Con todo, el objetivo de este trabajo fue doble. Primero, pretendía examinar el grado en el que estas características estaban presentes en estudiantes universitarios y, en segundo lugar, buscaba observar si tales características podrían modificarse tras implementar un programa de intervención.

399 participantes matriculados en estudios universitarios y con una edad comprendida entre los 18 y los 31 años (Medad= 22.04; Dt = 4.07) formaron parte del estudio. Los resultados indicaron que los estudiantes del grupo experimental que habían trabajado con la metodología el PBL mejoraban en los valores a los del grupo de control. Las conclusiones profundizan sobre la importancia de las actitudes y aptitudes asociadas al emprendimiento y sobre la utilidad de los programas de intervención para el fomento del emprendimiento en alumnado universitario.

Keywords: Emprendimiento; Programa de intervención; Aprendizaje basado en proyectos (PBL), Desarrollo de competencias socio-emocionales

1 Introducción

El desarrollo de la cultura emprendedora de los jóvenes vascos, es una de las necesidades que se perciben en la sociedad euskaldun. Nuestro pequeño país se ha caracterizado porque sus gentes a los largo de la historia ha dado muestras de su carácter emprendedor. Hoy en día necesitamos personas que compartan la cultura de emprender (Innobasque2010).

Con ese objetivo de fomentar esa actitud y los valores que subyacen en ella iniciamos entre los estudiantes universitarios un programa de intervención para el fomento de las actitudes. Con la finalidad de conocer hasta qué punto se mejora en las actitudes que fomentan la cultura emprendedora se realizaron una serie de mediciones, tanto a grupos experimentales (participantes en las sesiones de intervención) como a grupos de control que no participaban en ellas.

2 Contexto de la Cultura Emprendedora.

Existen un conjunto de características que definen a las personas emprendedoras (Baum, Frese & Baron, 2007). El análisis del comportamiento del emprendedor se ha centrado en la personalidad y motivación de los y las emprendedores/as. Así, hoy en día se reconoce que desde el análisis del comportamiento, a) la necesidad de logro, b) la necesidad de poder y c) la necesidad de afiliación son tres dimensiones fundamentales de toda persona emprendedora. Por otro lado, las variables cognitivas examinadas en la literatura demuestran que d) el locus de control, e) la perseverancia, f) la percepción del riesgo y g) la creatividad, constituyen dimensiones fundamentales para el fomento del emprendimiento. Sin estas actitudes y aptitudes, posiblemente una persona no llevará a cabo conductas de emprendimiento.

a) Necesidad de logro o motivación por la tarea

La necesidad o motivación de logro se define como el deseo que tienen ciertas personas por mejorar los resultados de su acción y de sentirse responsables de los mismos, se relaciona con la capacidad empresarial.

Es el impulso por sobresalir, por luchar para tener éxito más que por las recompensas del éxito en sí. Una persona con una elevada necesidad de logro pasa mucho tiempo considerando cómo hacer mejor su trabajo o cómo lograr algo importante para sí misma.

B) Necesidad de poder

Las personas emprendedoras muestran cierta necesidad de poder en el sentido de la autonomía y el poder de decisión que acompaña a sus actuaciones. El/la que emprende no tolera la autoridad que podría ejercerse sobre él/ella. La mayoría de las personas que deciden crear su empresa lo hacen para convertirse en su propio jefe/a. Además, algunos comentan que suelen ganarse la adhesión de sus empleados en lugar de su sumisión.

D) Locus de control o Responsabilidad

Hacer referencia al grado en que un individuo percibe el éxito y/o fracaso de su conducta como dependiente de sí mismo (locus de control interno) o del contexto (locus de control externo). Las personas con locus de control interno sienten que ellas controlan su vida y se creen dueños de su propio destino. Sin embargo, con locus de control externo piensan que otros controlan su vida y, por lo tanto, se ven a sí mismas como peones del destino y creen que lo que les sucede en la vida es producto del azar.

Las personas emprendedoras poseen un locus de control interno. Así lograr objetivos constituyen motores inagotables de autorrealización. Un optimismo constante guía al emprendedor sobre el curso de sus aprendizajes, en los cuales él se empeña en progresar y superarse, esperando hacerlo cada vez mejor. Una gran voluntad de logro alimenta también la autoconfianza del emprendedor. Esta les otorga la fuerza necesaria para recuperarse cuando sufren una seria derrota o una decepción.

Si bien el locus de control interno hace que la persona emprendedora organice su empresa de una manera centralizada, lo que le permite operar efectivamente y crecer en su etapa inicial; cuando la empresa ya está creada y comienza a crecer, ese alto nivel de centralización se convierte en un obstáculo, disminuyendo sus posibilidades de éxito. Por lo tanto, conviene gestionar el locus de control para garantizar la viabilidad de las empresas.

G) Creatividad e innovación

Las personas creativas poseen multitud de características de personalidad. Uno de los elementos que las definen son sus tipos de pensamiento. Poseen estilos de pensamiento divergente, es decir un tipo de pensamiento que busca alternativas o posibilidades creativas y diferentes para la resolución de un problema. Supone tener capacidad de replantearse un problema, buscar una nueva perspectiva en la percepción de la situación y un camino nuevo para abordar la solución de los problemas.

Si existe una idea de negocio, una coyuntura adecuada, un apoyo institucional suficiente y las personas poseen o desarrollan estas características serán personas que emprendan. De lo contrario, es muy probable que se queden en la idea o en el curso de formación y no den el salto al emprendimiento.

F) Asunción del riesgo

Podemos definir el riesgo como el grado de disposición que tienen las personas para asumir situaciones en las cuales su resultado es incierto. Así, la adopción de decisiones en ambiente de incertidumbre es uno de los aspectos que definen el rol empresarial, ya que si no existe una incertidumbre significativa, si la actuación adecuada al caso implica la aplicación de un procedimiento conocido, por muy complicado que sea, en orden a producir un resultado conocido y predecible, no puede decirse que ello lleve implícito un espíritu empresarial. La persona emprendedora busca el desafío, calcula metas alcanzables, tolera la ambigüedad, acepta el riesgo calculado (el riesgo que se administra) y estos aspectos son los que realmente le permiten seguir adelante. La aceptación del riesgo es percibida como necesaria para la consecución de los objetivos propuestos pues antes de poner en marcha una empresa considera su situación actual y la posibilidad de sacar adelante su idea.

C) Necesidad de afiliación, cooperación o solidaridad

Se entiende por afiliación el deseo de tener relaciones interpersonales amistosas y cercanas, en el caso de las personas emprendedoras la necesidad de afiliación tiende a ser baja. No debe confundirse con la capacidad de comunicación que les convierte en personas generalmente hábiles para integrarse en los grupos, unirse a los socios eventuales o encontrar relaciones útiles para su red. Las personas emprendedoras no buscan crear un grupo de amigos/as sino crear una realidad que les permitirá vehiculizar sus ideas.

E) Perseverancia, resiliencia o tenacidad

La perseverancia consiste en la firme persecución de un objetivo. La resolución positiva está renovada en cada nueva etapa. Es una persona trabajadora que no se deja abatir fácilmente. La persistencia constante será el más fuerte predictor del éxito en su faceta emprendedora. Se manifestará por una voluntad constante de buscar los enfoques diferentes y métodos nuevos en la resolución de problemas, pues tiene la firme determinación de lograr el objetivo a pesar del sacrificio personal.

Todos estos valores de la persona que ayudan a constituir la cultura personal emprendedora forman parte de la base de la pirámide del emprendimiento:

Imágen 1. Piramide del emprendimiento traducida y adaptada por la autora de la pirámide de Ennis, M. (2008)

3 Entornos identificados en MGEP para promover el emprendimiento.

El foco que se seleccionó para el desarrollo de la cultura emprendedora fue en el grado en Ingeniería en Organización Industrial, concretamente en el 6º semestre de la titulación. La intervenciones didácticas que en total fueron 6, están a disposición de todos los interesados, en el Departamento de Innovación de la Diputación de Gipuzkoa. http://www4.gipuzkoa.net/corporac/eco/ikasmina/emprendizaje/default.html

Con el objetivo de desarrollar las habilidades que se indican en la base de la pirámide, se definieron una serie de intervenciones didácticas basadas en la película Full Monty, en la que se analizaban los comportamientos de los protagonistas, y se reflexionaba sobre ellos. Tras esta reflexión y emparejamiento de los comportamientos con los valores emprendedores, lo estudiantes visualizaban una referencia o patrón de actuación.

Se seleccionaron varias secuencias de la película y se intentó, reflejar por medio de ella los valores que mostraban los protagonistas de la película. Los estudiantes veían la secuencia y describían los comportamientos que se observaban en ella. Tras ello se reflexionaba sobre el valor emprendedor que subyacía tras el comportamiento visionado.

Se describió la siguiente ficha didáctica:

Tabla 1. Ficha didáctica

Ficha didáctica
cha didáctica
Título: **Full Monty**
Intervención: **2º semestre de 201? en 3º de grado en Ingeniería en Organización Industrial**
Localización**: Mondragon Goi Eskola Politeknikoa. Mondragon Unibertsitatea**
Profesora**: Miren Itziar Zubizarreta**
Titulación: **Organización Industrial**
Número de participantes: **27 estudiantes**
Descripción breve**: En grupos verán diferentes escenas de la película Full Monty en las que tendrán que identificar los diferentes valores que se les han presentado y reflexionar a cerca de ellos.**
Objetivo**: Desarrollar aspectos relacionados con la asunción de riesgos, la responsabilidad, la innovación, la resiliencia y la cooperación.**

Tras este primer paso, de la observación y la reflexión sobre los valores emprendedores, los estudiantes habían de iniciar un proceso de activación de los comportamientos que los emprendedores: la asunción de riesgos, la cooperación grupal, innovación, solidaridad, responsabilidad y la resiliencia. Para activar estos valores y con el objetivo de reproducir comportamientos emprendedores de se utilizó la metodología PBL en el último semestre del grado de Ingeniería en Organización Industrial, para el desarrollo por parte de los estudiantes de las competencias de la Cultura Emprendedora.

Tabla 2. Intervención didáctica PBL

<table>
<tr><th colspan="2">ESTUDIO PARA EL LANZAMIENTO DE UNA ACTIVIDAD EMPRESARIAL</th></tr>
<tr><td>ÍNDICE
1. Introducción
2. Enunciado
3. Resultados de aprendizaje
4. Condicines de los entregables
5. Evaluación del Proyecto
6. Feedback</td><td>INTRODUCCIÓN
Las Nuevas Empresas de Base Tecnológica (NEBT) derivadas de la investigación universitaria son un mecanismo de transferencia de tecnología que contribuye a la mejora del sistema productivo de la región, crean riqueza y fomentan un entorno favorable para la creación a su vez, de otras empresas de base tecnológica. Se trata de una vía de transferencia entre la universidad y su entorno. Esto ha motivado que administraciones públicas y universidades hayan puesto en marcha mecanismos de fomento para la creación de spin-offs universitarias.
Con el objetivo de motivar el descubrimiento de oportunidades tecnológicas en la universidad y facilitar su comercialización vía spin-off, se pide a los futuros profesionales del ámbito de la Ingeniería, que partiendo de sectores emergentes elaboren un plan de negocio con el objetivo final de desarrollar habilidades de gestión y competencias que les capaciten para la creación de una empresa de base tecnológica.</td></tr>
<tr><td>ENUNCIADO
El proyecto está diseñado para que los estudiantes analicen la viabilidad técnica y económica, así como el potencial de negocio y crecimiento de las ideas y oportunidades detectadas dentro de un sector concreto, haciendo uso de una correcta gestión de proyectos y de la adecuada comunicación al entorno (clientes internos y externos). El sector en el cuál va a centrarse el trabajo de cada uno de los</td><td>Objetivos de aprendizaje:
• Desarrollar habilidades creativas
• Desarrollar habilidades de gestión y directivas, propias de lo que se conoce como cultura emprendedora.
• Adquirir actitudes proactivas y emprendedoras.
• Investigar, seleccionar y explotar la información.</td></tr>
</table>

grupos puede ser diferente. El grupo deberá centrar su actividad en uno de los siguientes ámbitos: 1. Deporte, ocio y juventud 2. Sostenibilidad y desarrollo rural 3. Energía y salud Para facilitar los aspectos, problemática e inquietudes reales sobre el tema (creación de un nuevo negocio), se ofrecerán diversas ponencias que versarán sobre distintos aspectos, con el objeto de promover el interés sobre las investigaciones y proyectos que analizan el desarrollo de empresas surgidas como respuesta diversas inquietudes de los promotores. Para la realización de este proyecto habrán de tenerse en cuenta los aspectos, contenidos, métodos y procedimientos que se trabajarán en los contenidos de Política Industrial y Tecnología, Marketing y Gestión de personas, Gestión de Proyectos, Ingeniería económica y Sistemas de información que se han impartido a lo largo de este semestre. A continuación se recogen algunas directrices para la realización del proyecto exponiendo cuáles son los objetivos que se pretenden conseguir.	• Comunicar eficientemente los resultados obtenidos y defender una idea de negocio frente a eventuales inversores. • Realizar una memoria y exponer el trabajo realizado en inglés. • Sintetizar el trabajo realizado elaborando un póster.

La realización del proyecto hará que los estudiantes adopten comportamientos propios de los emprendedores, pero también una manera de actuar emprendedora.

Antes de iniciar las intervenciones didácticas en el aula, se pidió a los estudiantes cumplimentaran un cuestionario para medir las percepciones que éstos tenían sobre los comportamientos emprendedores que ellos tenían y después de realizar el proyecto utilizando la metodología PBL se volvió a pasar el cuestionario en este grupo, se utilizó también un grupo de control para ver si era precisamente la realización del PBL la que fomentaba o era el propio desarrollo de los estudiantes.

4 Los Datos

A continuación en la tabla 3, mostramos los datos tratados estadísticamente, referidos al pretest, es decir, antes de cualquier intervención tanto en el grupo experimental como en el grupo de control.

Tabla 3: Diferencias entre el grupo control y el experimental antes del programa de intervención

Pretest	**Media Grupo Expe.**	**DT**	**Media Grupo Control**	**DT**	**T**	**Sig.**
Arduratasuna-Responsabilidad	5.03	0.47	4.98	0.48	0.59	0.55
Berrikuntza-Innovación	3.79	0.73	3.79	0.91	-0.04	0.91
Elkartasuna-Solidaridad	4.87	0.67	4.65	0.65	1.85	0.07
Arrisku hartzea-Asunción de riesgos	3.63	1.03	3.86	0.92	-1.35	0.17
Talde Lankidetza-Cooperación Grupal	5.10	0.46	4.88	0.60	2.23	0.03
Erresilientzia-Resiliencia	4.78	0.53	4.65	0.55	1.35	0.18

Como puede observarse en los resultados, únicamente en la dimensión de COOPERACIÓN GRUPAL mostró diferencias estadísticamente significativas entre el grupo experimental y el grupo control, mostrando el primero- grupo experimental- valores superiores. Por lo tanto, puede concluirse que ambos grupos, antes del inicio de la intervención, mostraban resultados similares en la mayoría de las dimensiones examinadas, por lo que es pertinente comparar las puntuaciones tras la intervención.

Posteriormente, con objeto de analizar si el grupo experimental (receptor de la intervención) mostraba puntuaciones superiores en los valores analizados antes y después de la intervención, se llevó a cabo una comparación de medias en los valores de referencia para el grupo experimental. Los resultados se muestran en la Tabla 4.

Tabla 4: Comparación de medias para el grupo experimental antes y después de la intervención.

Grupo Experimental	**Pretest**		**Postest**			
	Media	**DT**	**Media**	**DT**	**T**	**Sig.**
Arduratasuna-Responsabilidad	5.03	.472	5.15	.428	-1.62	.11
Berrikuntza-Innovación	3.79	.736	4.07	.934	-1.97	.04
Elkartasuna-Solidaridad	4.87	.674	4.91	.538	-.321	.74
Arrisku hartzea-Asunción de riesgos	3.63	1.03	3.92	.987	-1.20	.23
Talde Lankidetza-Cooperación Grupal	5.10	.461	5.09	.537	.102	.91
Erresilientzia-Resiliencia	4.78	.530	4.75	542	.383	.70

Se examinó el logro de objetivos del programa de intervención a través de la comparación de medias en los valores de referencia para el emprendimiento. Se compararon los valores medios de cada uno de los seis valores antes y después de la intervención. Así, se observó que únicamente se produce un incremento en la percepción de INNOVACIÓN de los participantes en el programa. También se observa que la RESPONSABILIDAD respecto a las decisiones adoptadas incrementa antes y después de la intervención, dado que su tamaño del efecto es moderado.

Con objeto de examinar posibles efectos de maduración o examinar otros efectos de variables espúreas que hayan podido influir en el cambio de resultados durante el tiempo transcurrido entre el antes y el después de la intervención, se llevó a cabo una comparación de medias para muestras relacionadas para el grupo de control. Los resultados pueden observarse en la Tabla 3.

Tabla 5: Comparación de medias para el grupo control antes y después de la intervención.

Grupo Control	**Pretest**		**Postest**			
	Media	**DT**	**Media**	**DT**	**T**	**Sig.**
Arduratasuna-Responsabilidad	5.03	.436	4.89	.709	1.02	.31
Berrikuntza-Innovación	3.78	.858	3.81	.935	-.232	.81
Elkartasuna-Solidaridad	4.64	.590	4.59	.681	.400	.69
Arrisku hartzea-Asunción de riesgos	3.82	.988	3.73	1.01	.454	.65
Talde Lankidetza-Cooperación Grupal	4.79	.574	4.89	.546	-1.01	.31
Erresilientzia-Resiliencia	4.55	.616	4.67	.656	-1.03	.30

La Tabla 5 muestra que, tal y como se esperaba, no existen diferencias estadísticamente significativas entre las puntuaciones transcurrido el tiempo de la intervención. Por lo que obtenemos más evidencias de que los cambios producidos en el grupo experimental, objeto de la intervención, pueden haber sido consecuencia del programa implementado.

A fin de corroborar este extremo se examinó si, efectivamente, las puntuaciones del grupo experimental eran superiores a las del grupo control tras la intervención a las puntuaciones observadas antes de la intervención. Al igual que en el análisis precedente de la Taula 20, se ha examinado el grado en el que el grupo control (no ha participado en el programa) y experimental (ha participado en el programa) son sustancialmente distintos en los valores examinados tras la intervención. Para ello se llevó a cabo un análisis de comparación de medias para muestras independientes.

Tabla 6: Diferencias entre el grupo control y el experimental después del programa de intervención

Postest	Media Grupo Expe.	DT	Media Grupo Control	DT	T	Sig.
Arduratasuna-Responsabilidad	5.15	.428	4.89	.709	2.17	0.032
Berrikuntza-Innovación	4.07	.934	3.81	.935	1.55	0.124
Elkartasuna-Solidaridad	4.91	.538	4.59	.681	2.55	0.012
Arrisku hartzea-Asunción de riesgos	3.92	.987	3.73	1.01	.89	0.373
Talde Lankidetza-Cooperación Grupal	5.09	.537	4.89	.546	1.58	0.117
Erresilientzia-Resiliencia	4.75	542	4.67	.656	.288	0.774

Tal y como puede observarse en la Tabla 6 el grupo experimental y el grupo control muestran puntuaciones distintas tras la intervención. Específicamente, el grupo experimental muestra valores superiores estadísticamente significativos en las dimensiones de RESPONSABILIDAD Y SOLIDARIDAD. Además, cabe mencionar, que los análisis de tamaño del efecto indican que con muestras superiores las dimensiones de INNOVACIÓN Y COOPERACIÓN GRUPAL también hubieran mostrado niveles estadísticamente significativos. Así, cabe mencionar que el programa de intervención llevado a cabo ha alcanzado prácticamente el 70% de los objetivos establecidos aumentando las puntuaciones de cuatro de los seis valores analizados.

5 Conclusiones

Podemos concluir según los resultados del programa sobre comportamientos asociados a los valores de emprendimiento examinados que la utilización del PBL como metodología de aprendizaje fomenta los comportamientos que configuran los valores del emprendimiento.

Así, parece que el programa ha mejorado sustancialmente las puntuaciones asociadas a los valores de RESPONSABILIDAD, SOLIDARIDAD, INNOVACIÓN Y COOPERACIÓN GRUPAL en la muestra experimental (es decir, la receptora de la intervención) aspecto no observado en el grupo control. De este modo, cabe mencionar que el programa de intervención didáctica llevado a cabo ha alcanzado los objetivos establecidos.

Este hecho, hace aconsejar su replicación y extensión a otras muestras y otras universidades y caminar, en este sentido, hacia el objetivo inicial del proyecto de asentar las bases para crear una ciudadanía en la que los valores asociados al emprendimiento y la proactividad se desarrollen desde la formación. El objetivo, en este sentido, es compartir y contrastar la experiencia y poder mejorar tanto los itinerarios formativos como los sistemas de medida y control con las lecciones aprendidas en las posteriores implantaciones del programa pilotado en esta investigación sobre la conveniencia de utilizar la metodología PBL.

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The use of the project based learning with undergraduate students of industrial and logistics engineering to analyse the distribution process of a commercial company of beauty products, in order to increase the efficiency of their process

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Abstract

The objective of the study was to analyse the distribution process of a commercial company in the industry of beauty products in the region, in order to identify opportunities for improvement, whose implementation will increase the efficiency of your process. In order to identify those areas the workgroup included to undergraduate students in Industrial Engineering Logistics at the Autonomous University of Yucatán and a recently graduated from the same study field to strengthen the powers in a real problem. The methodology consisted of a series of activities based in project-oriented learning as followed: tours of the facilities, staff interviews, gather information, mapping the value stream (first level processes), mapping processes to the second level, the analysis of value-added processes, identify findings and impacts on process efficiency and identify and prioritize improvement opportunities. Improvement opportunities were identified from the structural type. Finally a matrix was performed to determine the impact of implementing each in the business and the cost of the project to meet the challenge of the company, that the goods arrive from customs to the customer's hands: as quickly as possible, with the right amounts, without error and without damage to have in bank monetary value as possible.

Keywords: project-based learning, value-added, distribution process, improvement opportunity, mapping.

Utilización del Aprendizaje Basado en Proyectos con los estudiantes de Ingeniería Industrial Logística para incrementar la eficiencia del proceso de distribución en una comercializadora de productos de belleza

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Abstract

El Objetivo del trabajo fue analizar el proceso de distribución de una empresa comercializadora del ramo de productos de belleza de la región, con el propósito de identificar áreas de oportunidad para la mejora, cuya implementación incrementará la eficiencia de su proceso. Para poder identificar esas áreas se integraron en el grupo de trabajo a una estudiante de la licenciatura en Ingeniería Industrial Logística de la Universidad Autónoma de Yucatán y a un recién egresado de la misma, para reforzar las competencias de su área de estudio en un proyecto real. Se siguió una metodología basada en el aprendizaje basado en proyectos que consistió en una serie de actividades como: recorridos a las instalaciones, entrevistas al personal, colectar información, mapear el flujo de valor (procesos a primer nivel), mapear los procesos a segundo nivel, realizar el análisis de valor agregado de los procesos, identificar hallazgos e impactos en la eficiencia de los procesos e identificar y priorizar las oportunidades de mejora. Mediante la aplicación de la metodología se identificaron nueve hallazgos y para cada uno de ellos se definieron diez oportunidades de mejora cuatro de ellas del tipo estructural. Finalmente se realizó una matriz para poder determinar el impacto de la implementación de cada una de ellas en el negocio y el costo del proyecto, para poder cumplir con el reto de la empresa. Que la mercancía llegue desde la aduana hasta las manos del cliente: lo más rápido posible, con las cantidades correctas, sin errores y sin daños; para disponer en banco de su valor monetario lo antes posible.

Keywords: aprendizaje basado en proyectos, valor agregado, distribución, proceso, oportunidad de mejora, mapeo.

1 Introducción

El Aprendizaje Basado en Proyectos implica el formar equipos integrados por personas con perfiles diferentes, áreas disciplinares, profesiones, idiomas y culturas que trabajan juntos para realizar proyectos para solucionar problemas reales. Estas diferencias ofrecen grandes oportunidades para el aprendizaje y prepararan a los estudiantes para trabajar en un ambiente y en una economía diversa y global. Para que los resultados del trabajo de un equipo, bajo el Aprendizaje Basado en Proyectos sean exitosos, se requiere de un diseño instruccional definido, asignación de roles y fundamentos de diseño de proyectos.

El Aprendizaje Basado en Problemas puede ser un proyecto de investigación, un caso de estudio, un proyecto de diseño, una situación de contingencia, un encuentro clínico, un enfoque educacional llamado diseño guiado o un grupo pequeño de aprendizaje auto-dirigido y auto-evaluado. Frecuentemente las opciones dependen de quién sea el responsable de dirigir la actividad: el profesor o el estudiante (Woods, 2002).

En este estudio se trabajó con un proyecto de vinculación entre la Universidad y una empresa comercializadora de productos de belleza, quien se acerco a la Facultad con un problema. Como parte del nuevo modelo educativo de formación integral de los estudiantes de la Universidad Autónoma de Yucatán donde la educación se centra en el estudiante como el propio diseñador de su aprendizaje mediante el desarrollo de competencias, se integró al grupo interdisciplinar ejecutor del proyecto a una estudiante del octavo semestre de la licenciatura en Ingeniería Industrial Logística y un recién egresado de la misma.

El estudiante aplicó los conocimientos adquiridos previamente de las asignaturas Control de Calidad, Sistemas de Calidad, Ingeniería de Métodos, Administración, Investigación de Operaciones, Medición y Evaluación en el Área Laboral, Almacenes, Abastecimiento al realizar algunas de las siguientes actividades: realización de entrevistas, diagramación de procesos, mapeo de flujos de valor, análisis de valor agregado, estructuración organizacional, programación y control de actividades del proyecto, medición y análisis del desempeño de las operaciones de los procesos, toma de tiempos, elaboración de gráficas de control de calidad y diagramación de recorridos.

Todas estas actividades fueron tutoradas por el líder del proyecto que a su vez es el coordinador de la licenciatura del estudiante.

2 Objetivo General

Aplicar la metodología del aprendizaje basado en proyectos para potenciar las capacidades de auto aprendizaje del estudiante, desarrollando las siguientes competencias primarias como menciona (Galeana, 2006):

- Crear un concepto integrador de las diversas áreas del conocimiento.
- Promover una conciencia de respeto de otras culturas, lenguas y personas.
- Desarrollar empatía por personas.
- Desarrollar relaciones de trabajo con personas de diversa índole.
- Promover el trabajo disciplinar.
- Promover la capacidad de investigación.
- Proveer de una herramienta y una metodología para aprender cosas nuevas de manera eficaz.

2.1 Objetivos específicos

- Apoyar a la empresa con el cumplimiento de su objetivo de negocio que consiste en hacer que la mercancía llegue desde la aduana hasta las manos del cliente lo más rápido posible, sin errores, sin daños, con las cantidades requeridas y al mínimo costo.
- Apoyar a la empresa a que su personal identifique oportunidades de mejora a través de un enfoque de procesos y considerando la eliminación del desperdicio y las actividades que no agregan valor.
- Identificar oportunidades de mejora para que, por medio de su implementación, mejore la eficiencia del proceso de distribución lo cual permitirá disponer en el banco del valor monetario de la mercancía, lo antes posible.

2.2 Antecedentes

La empresa Comercializadora Michelle, es una empresa familiar dedicada a la distribución de accesorios para dama; Cuenta con más de 250 empleados que laboran en las áreas operativas de almacenamiento y distribución, así como con vendedoras y jefas de tiendas que trabajan en sus sucursales (tiendas Michelle). Gestionan en sus almacenes más de 7,500 referencias (SKU´s).

En Mérida, Yucatán se encuentran sus oficinas centrales y los 2 almacenes principales que gestionan la distribución de la mercancía hacia las 47 sucursales con lo que cubren un mercado local y nacional. Sus principales proveedores se localizan en China.

2.3 Problemática

La empresa cuenta con un proceso clave de negocio que es el de “Distribución”, el cual inicia cuando llega el material al almacén de la comercializadora proveniente de la aduana, y finaliza cuando la mercancía es enviada desde el almacén de resurtido a las sucursales.

El proceso de distribución, de acuerdo a la preocupación expresada por el dueño de la empresa, cuenta con ineficiencias y atrasos en los tiempos de entrega. Debido a que Comercializadora Michelle está en el negocio de la moda, el beneficio (ingreso) está relacionado con la velocidad con la que el cliente puede disponer de los productos en los puntos de venta (sucursales).

Por lo cual es importante que los tiempos de ciclo de los procesos de distribución sean eficientes y cumplan con los requisitos de tiempo de entrega solicitados ya sean por sus clientes internos (sucursales) y también por sus clientes finales (compradores). La problemática está directamente relacionada con los tiempos de proceso de las actividades realizadas tanto en su almacén de "Recepción y distribución" como en su almacén de "Resurtido".

3 Metodología

El desarrollo del proyecto se realizó bajo la supervisión del coordinador de la carrera de Ingeniería industrial logística que a su vez es profesor de la institución y consultor externo; como enlace entre la empresa y la Universidad se integró al responsable de vinculación; un profesor asumiendo el rol de asesor, y para la ejecución operativa del proyecto un estudiante y un recién egresado de la carrera.

El análisis del proceso de "Distribución" fue realizado por el estudiante y el recién egresado quienes sostuvieron reuniones semanales con el líder del proyecto para su revisión y aprobación para continuar con las siguientes fases. A continuación se listan los siguientes factores que se evaluaron:

a) La Estrategia y Estructura: para conocer la visión y los objetivos estratégicos a corto y mediano plazos de *Comercializadora Michelle* que influyen en su estructura, en sus políticas, en sus procesos, sus métodos de trabajo y en sus reportes.

b) La Tecnología: para conocer los esquemas, las soluciones, la estructura y los recursos tecnológicos que soportan las operaciones actuales.

c) La Gente: para comprender el grado de involucramiento y de compromiso de las personas que trabajan en la empresa; escucharlos y considerar sus percepciones y opiniones.

d) Los Procesos y los métodos de trabajo: para identificar y definir los procesos involucrados en la operación y en las actividades que actualmente se realizan, tomando en cuenta el entorno y la operación global en que se encuentran inmersos.

e) La infraestructura: para identificar las instalaciones, equipos y edificios que contribuyen actualmente a la ejecución de las operaciones.

Para poder mejorar la eficiencia en el "Proceso de Distribución" se requiere eliminar (o minimizar) los factores que generan ***Desperdicio y Tiempo sin Valor Agregado*** para incrementar la eficiencia y disminuir los costos del proceso tal y como se muestra en la figura 1.

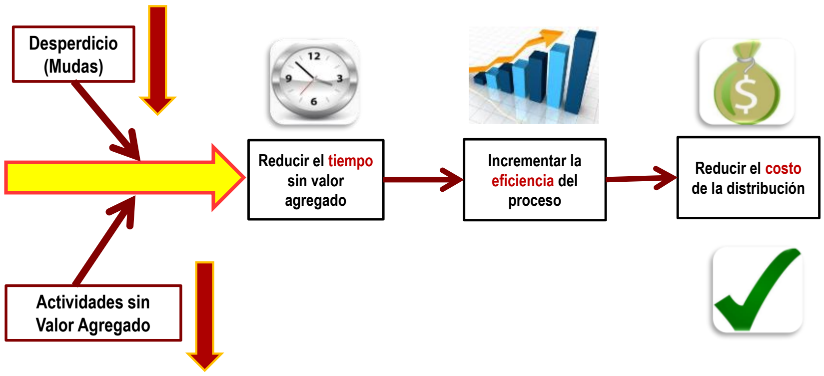

Figura 1: Diagrama de reducción de desperdicios.

La **eficiencia** es la relación entre las salidas de un proceso con respecto a los recursos utilizados para procesar estas salidas. Cuando se disminuye la utilización de recursos mejora la eficiencia de las operaciones y se contribuye a mejorar la productividad. En la figura 2 podemos observar que **la reducción del desperdicio y**

de las actividades sin valor agregado aumenta la eficiencia y reduce los costos operativos, en este caso disminuye el costo del "Proceso de Distribución" de la comercializadora.

Las actividades con valor agregado *("Customer Value Add")* son el trabajo que contribuye a lo que los clientes quieren obtener del producto o servicio y que pagarían por esto si supieran que se realiza. (George, 2003)

Las actividades sin valor agregado (*"non-value-add"*) son el trabajo que no agrega valor a los ojos de los clientes y que no están dispuesto a pagar por ello.

Las actividades de un proceso agregan valor[4]:

- Si el cliente la considera importante: la valora y paga por ella.
- Si contribuye a reducir el precio, a agilizar la entrega, etc.
- Si agrega una función, forma o característica deseada al producto o al servicio.
- Si no es un re-trabajo (si se realiza bien desde la primera vez que se hace)

Las actividades de un proceso son necesarias:

- Si son requeridas por leyes gubernamentales, normas o reglamentos (consideraciones de salud, seguridad, fiscal, medio ambiente, etc.)
- Por restricciones mismas de la organización (políticas internas, objetivos estratégicos; disponibilidad de recursos como personal, tecnología, infraestructura, etc.)
- Si contribuyen a la prevención de errores, defectos o fallas; o para reducir riesgos de la Organización.

El **desperdicio** es cualquier actividad o uso de recursos que **no le agrega valor** al producto o al servicio final **desde la perspectiva del cliente** (Ohno, 1988) y (Jones, 2003). Este afecta la eficiencia de los procesos de transformación, administrativos y de servicios.

Existe diferentes tipos de desperdicio ("*Mudas*") los cuales se en listan a continuación. (Hernández, 2013)

1. **Por sobreproducción.** Se encuentra cuando se produce más producto de lo que se requiere en ese momento por sus clientes. Una práctica común que conduce a esta muda es la producción de grandes lotes. La sobreproducción conduce a exceso de inventario, el cual requiere el gasto de los recursos de espacio de almacenamiento y conservación, actividades que no benefician a los clientes**.**
2. **Por esperas.** Este desperdicio aparece siempre y cuando los bienes no se encuentren transportándose o en trámite, sino que se encuentren parados a la espera de su proceso productivo.
3. **Por transportación.** Cada vez que un producto es movido, tiene el riesgo de ser dañado, perdido, tener retraso, entre otros. La razón de que no sea un proceso de valor agregado es que la transportación en sí, no hace ninguna transformación al producto que el cliente está dispuesto a pagar.
4. **Por inventarios.** Representa un desembolso de capital, que aún no ha producido un ingreso, ya sea por el productor o para el consumidor.
5. **Por movimientos.** Cualquier movimiento del cuerpo de una persona o de un equipo que no le agregue valor al producto o en el que trabaja.
6. **Por sobre-procesamiento.** Trabajo adicionado al producto que no es valor agregado para el cliente. Incluye revisiones y aprobaciones redundantes y las operaciones para re-trabajar, reparar, reemplazar o desechar productos que no cumplen los requisitos.

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[4] Adaptado de (George, 2003)

7. **Por productos o servicios no conformes.** Cada vez que aparecen imperfecciones, se incurre en costos adicionales reelaboración de la parte, reprogramación de producción, etc. Los defectos en la práctica a veces puede duplicar el costo de un solo producto.

La figura 2 muestra el flujo del proceso en el almacén de la comercializadora. En esta gráfica se observa el mapa general de todas las actividades identificadas por el estudiante y el recién egresado durante el análisis.

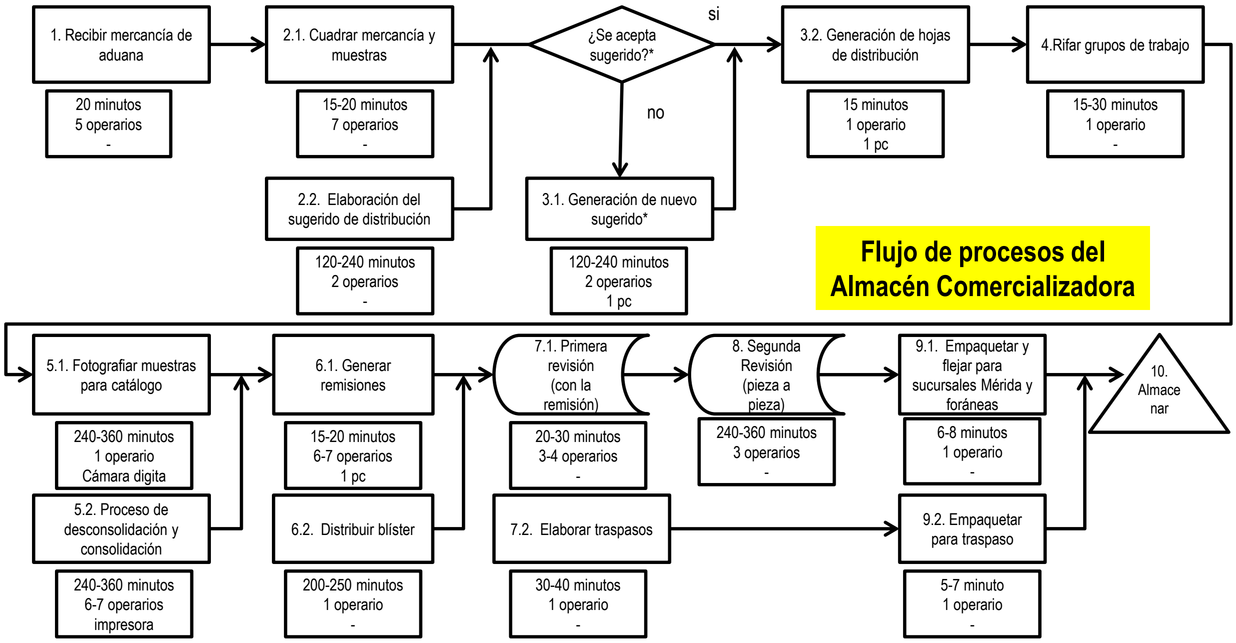

Figura 2: Flujo de procesos del Almacén Comercializadora

El tiempo empleado por el estudiante y el egresado para el levantamiento de la información fue de un mes, presentando reportes semanales al grupo asesor antes mencionado como se observa en la figura 3.

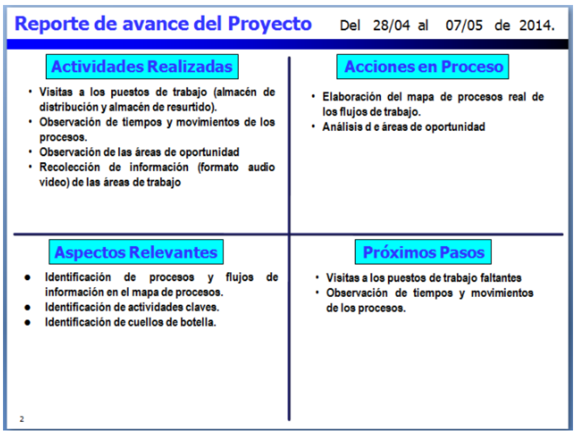

Figura 3: Formato de avance semanal de los estudiantes.

4 Resultados

A continuación se presentan de manera compacta los hallazgos encontrados en las diferentes actividades específicas de los procesos analizados:

- *HA-01:* Pérdida de tiempo en actividades que no agregan valor (por ejemplo: rifa de equipos, organizar y acomodar mercancía nueva).
- *HA-02:* Hay actividades que no siguen un procedimiento o que se realizan de manera discrecional.
- *HA-03:* Existen varios espacios de almacenamiento dispersos dentro de los mismos almacenes, esto ocasiona movimientos sin valor agregado del personal y mayores áreas de almacenamiento.
- *HA-04:* Los operarios no realizan actividades de valor agregado en períodos de espera de mercancía. Por ejemplo, en el almacén de recepción y distribución, mientras no llega mercancía los operarios no realizan ningún trabajo referido a distribución.
- *HA-05:* La distribución de áreas de almacén está mal diseñada por lo que crea ineficiencias en los la actividades (cuellos de botella). Por ejemplo, el almacén de resurtido se encuentra en segundo piso y es necesaria la utilización de un elevador para mover la mercancía.
- *HA-06:* Se realizan re trabajos por falta de calidad en la fuente. Por ejemplo: empaquetar, verificar y revisar en más de una ocasión.
- *HA-07:* Se genera desperdicio de insumos. Por ejemplo, al encintar las cajas para pasarlas revisión.
- *HA-08:* Se ocasionan retrasos para el inicio de la actividades debido a otras actividades dependientes que conllevan un retraso.
- *HA-09:* Existen demoras en las operaciones debido a equipo insuficiente (como la flejadora y vehículos), que falla (como impresoras), o por saturación del Sistema Integral Michelle (lentitud del sistema).

Adicionalmente se propone una lista de oportunidades de mejora que, de manera estructural, contribuirán a mejorar la eficiencia de todas las operaciones del negocio complementando la implementación de las oportunidades identificadas en el análisis de los procesos de la Comercializadora.

- ***OM-7*:** Integrar todas las operaciones de la empresa, incluyendo a las sucursales, mediante tecnologías de información y de comunicaciones ("TIC´s").
- ***OM-8**:* Contar con un almacén general (CEDIS) con un diseño adecuado para las operaciones actuales y futuras de la empresa.
- ***OM-09**:* Fortalecer las habilidades de gestión de los mandos medios de la empresa:
- ***OM-10:*** Diseñar un sistema de incentivos al personal:

5 Conclusiones

- Mediante la aplicación de la metodología de aprendizaje basado en proyectos que incorpora a estudiantes para el reforzamiento de sus competencias en la resolución de problemas reales que día a día enfrentan las empresas, se proporcionó un ambiente real a dos estudiantes los cuales pudieron mejorar sus relaciones interpersonales y sus habilidades para el trabajo en equipo.
- La estudiante paso por todas las fases del Aprendizaje basado en proyectos definidos por Grant (2011) que van desde la fase introductoria al problema, asignación de tareas guiadas y dirigidas, proceso de investigación en campo, utilización de diversos medios de información como libros de consulta, ligas para reforzar las propuestas de solución del problema.
- Como parte de una de las etapas la estudiante realizó presentaciones al grupo consultor y posteriormente dio a conocer su experiencia en un evento académico especializado mediante una ponencia oral frente otros estudiantes y profesores, realizando así actividades de extensión. Por otro

lado la presentación de resultados a la empresa fue realizada por el recién egresado obteniendo comentarios satisfactorios por parte del empresario y su grupo de trabajo.

- Cabe resaltar que para la estudiante fue su primera experiencia de trabajo con un equipo consultor lo cual ha sido de gran valor en su formación académica y curricular.
- Con el nuevo Modelo Educativo para la Formación Integral del estudiante (UADY, 2012) la Universidad Autónoma de Yucatán estará integrando este tipo de aprendizaje en sus distintas licenciaturas con la finalidad de responder de forma pertinente al compromiso social de la Universidad, por medio de la articulación de seis ejes: educación centrada en el aprendizaje, educación basada en competencias, responsabilidad social, innovación, flexibilidad e internacionalización.

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Curricular transformation of electrical engineering program at the Pascual Bravo University Institution

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Abstract

The Pascual Bravo University institution has worked in a curricular reform process, including the program of electrical engineering. This program was restructured based on guidelines of the Ministry of National Education and the Colombian Association of Faculties of Engineering (ACOFI). Professional and occupational profiles were updated with competence education model as a reference, obtaining a new curriculum currently supported by the Ministry of Education for its operation.

Keywords: Curriculum design; engineering education; Competences.

Transformación Curricular del programa de Ingeniería Eléctrica de la Institución Universitaria Pascual Bravo

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Resumen

La Institución universitaria Pascual Bravo ha trabajado en el proceso de reforma curricular de sus programas, entre ellos la Ingeniería Eléctrica. Este programa fue reformado basado en lineamientos del Ministerio de Educación Nacional y directrices de la Asociación Colombiana de Facultades de Ingenierías (ACOFI). Se actualizaron los perfiles profesional y ocupacional con el modelo de educación por competencias como referente, obteniendo un nuevo plan de estudios actualmente avalado por el Ministerio de Educación Nacional para su funcionamiento.

Palabras claves: Diseño curricular; Educación en Ingeniería; Competencias.

1 Introducción

Según (Parra Acosta, 2006) los cambios continuos y sucesivos en los sistemas productivos, financieros, en la tecnología y la ciencia, propician nuevas formas de vida, de producción y de trabajo; lo que conlleva a que las Instituciones de Educación Superior dirijan sus propósitos educativos a la formación integral. Desde hace varios años, las Instituciones de Educación Superior, se han visto inmersas en un proceso de reforma curricular para establecer una relación más efectiva con la problemática social (Parra Acosta, 2006).

Este proceso de reforma curricular conlleva modificar planes y programas transitando en diferentes modelos educativos, entre ellos el modelo de competencias centrado en el aprendizaje, donde las competencias se definen como un conjunto de actitudes, habilidades y conocimientos que se expresan mediante desempeños relevantes para dar solución a la problemática social, así como para generar necesidades de cambio y de transformación. Implican un saber conocer, saber hacer, saber convivir y saber ser (Parra Acosta, 2006).

La propuesta para rediseñar planes y programas de estudio flexibles inscritos en este modelo educativo basado en competencias, se desarrolla en siete pasos a través de un proceso de planeación estratégica y prospectiva los cuales son descritos en la Figura 1, esto con el fin de diseñar planes y programas de estudio congruentes con las carencias y la problemática de la sociedad, así como con las necesidades de formación de los estudiantes.

Continuando con la educación por competencias, esta se basa en un enfoque sistémico y complejo donde se evidencia una necesidad impostergable en el desarrollo de la Educación Superior en general y en el caso del ingeniero en particular para los nuevos paradigmas y desafíos del Tercer Milenio con un enfoque de Desarrollo Humano Integral (Isis Cerato & Gallino, 2013). Los mapas curriculares de los Planes de Estudio de las carreras de ingeniería, de forma tradicional han incluido competencias específicas en las asignaturas que los conforman, sin embargo, los cambios debidos al proceso de globalización en los mercados laborales, obliga a que se incluyan las competencias genéricas tanto en su perfil de egreso como en sus mapas curriculares (Segovia Orozco, Salmerón Guzmán, & Tovar Corona, 2013) donde las competencias profesionales se encuentran conformadas por las competencias específicas y las competencias genéricas; las cuales dan sustento a la formación del estudiante y se integran en el perfil de egreso en conjunto con su campo del quehacer laboral (Segovia Orozco, Salmerón Guzmán, & Tovar Corona, 2013).

Por otra parte, la educación es una ciencia, y como tal a lo largo de su historia muchas han sido las “verdades superadas” como le ha correspondido a todas las otras ciencias como razón interna de cientificidad. El conductismo, el gestaltismo, el cognocitivismo, el aprendizaje significativo y el constructivismo forman partes de ese viaje, en términos de las teorías del aprendizaje. Igualmente el currículo, como parte de esta ciencia, se caracteriza por los avances en las áreas de su especialización. En este sentido, entran en juego una serie de elementos que permiten el desarrollo de experiencias de aprendizaje, que han avanzado desde la observación de cambios de conductas, por objetivos y modernamente, el currículo por competencias (Negrón, Flores, & Angulo, 2013).

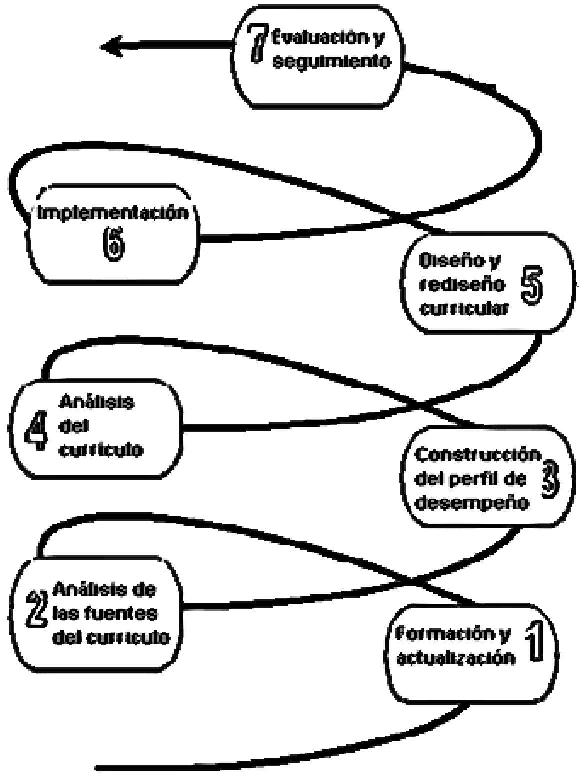

Figura 1: Propuesta metodológica para el diseño curricular (Parra Acosta, 2006)

2 Metodología

El aprendizaje basado en competencias requiere que las Instituciones de Educación Superior, en este caso la Institución Universitaria Pascual Bravo se replantee respecto al esquema de respuesta educativa al contexto social que se ofrece (Figura 2), propendiendo al cambio enfocado al modelo.

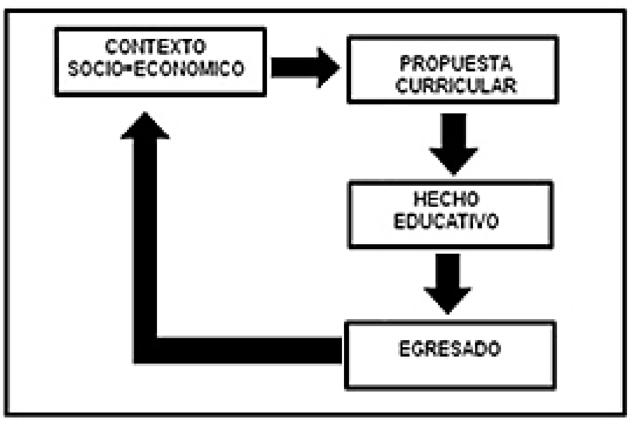

Figura 2: Esquema de respuesta educativa al contexto social de la educación universitaria (Negrón, Flores, & Angulo, 2013)

Para el caso de aplicación de la reforma curricular de la Ingeniería Eléctrica en la Institución Universitaria Pascual Bravo se propende la aplicación del modelo propuesto por (Negrón, Flores, & Angulo, 2013) el cual consta de fases o estaciones en la secuencia establecida en el mismo y con un proceso interminable en la acción de aprender (Figura 3). Así, un aprendizaje conlleva al logro de otro, y este último será el previo, siempre que tengan relación. Las fases del modelo se precisan así: 1. Conocimiento previo logrado a través del aprendizaje significativo, 2. El docente cumple el papel de facilitador para que el aprendiente establezca las similitudes, contradicciones y diferencias que existan en el contenido que se pretende apropiarse, 3. Tanto el docente como el participante elaboran un discurso que tenga pertinencia en cuanto a la actualidad, la concreción y recurriendo a hechos del entorno, 4. El estudiante exterioriza mediante la vía más expedita el proceso que le ha permitido interpretar la nueva situación de aprendizaje, y dialécticamente reformula el aprendizaje previo, logrando el nuevo aprendizaje significativamente.

Basados en este modelo y en el medio ocupacional de los estudiantes se planteó el perfil profesional y en base a este y las competencias necesarias para satisfacer el perfil del egresado se llegó al encuentro de los saberes , evidenciándose estos en las asignaturas propuestas para el plan de estudios- Es de destacar la participación en comités curriculares por parte de docentes, dicentes, egresados y sector productivo lo que llevo a la interacción activa en discusiones académicas y curriculares , creando espacios de participación parte invaluable en el proceso de transformación curricular. Las competencias y saberes identificados fueron adaptados al decreto 1295 de 2010 del Ministerio de Educación Nacional y bajo los estándares de la Asociación Colombiana de facultades de Ingenierías (ACOFI).

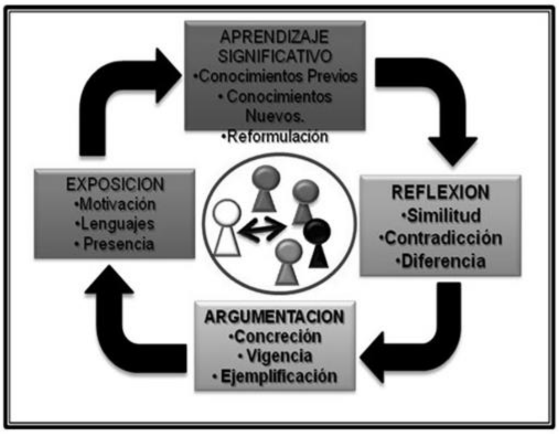

Figura 3: Modelo del hecho educativo basado en competencias para el logro del aprendizaje significativo de los estudiantes universitarios (Negrón, Flores, & Angulo, 2013)

3 Resultados

Se presenta el perfil profesional: La Institución Universitaria Pascual Bravo forma un profesional en Ingeniería Eléctrica con gran capacidad de trabajo en equipo, compromiso social y liderazgo empresarial; capaz de administrar el recurso humano y proteger el medio ambiente. El perfil ocupacional o del egresado se basa en las competencias, el contexto, y el campo del saber. Dichas competencias son expuestas en la tabla 1

Tabla 1: Pertinencia Social de la Ingeniería Eléctrica en la Institución Universitaria Pascual Bravo.

Campo de Intervención	Contexto	Objeto de formación (perspectivas)	Competencias en el saber hacer profesional
Los Sistemas Eléctricos (SE).	Los sectores industrial, comercial y residencial con el propósito de satisfacer necesidades en materia de suministro de energía eléctrica.	Diseño e implementación de Sistemas Eléctricos	Diseñar e implementar sistemas de generación de energía eléctrica, sistemas de transporte de energía eléctrica e instalaciones eléctricas industriales, comerciales, residenciales y de alumbrado público, seleccionando sus componentes de acuerdo a las especificaciones de complejidad, confiabilidad y seguridad, cumpliendo en todo momento con las normas de seguridad industrial, medioambientales y las propias del sector. Diagnosticar e intervenir el estado de los SE diseñando y ejecutando planes de mantenimiento, para conservar sus condiciones originales de funcionamiento, cumpliendo en todo momento con las normas de seguridad industrial, medioambientales y las propias del sector.
		Automatización, reconversión y modernización de Sistemas Eléctricos	Optimizar los procesos de generación, transporte y uso de la energía eléctrica mediante la reconversión y modernización de los SE. Diseñar e implementar proyectos fundamentados en el uso de Energías alternativas. Diseñar e implementar proyectos de Automatización de SE
		Diseño, gestión y ejecución de proyectos eléctricos	Diseñar, implementar y controlar la ejecución de proyectos de SE. Gestionar y administrar proyectos de uso racional de la energía.

La pertinencia académica, es decir las asignaturas necesarias para alcanzar las competencias en el saber profesional son relacionadas en la Tabla 2, donde se describen las competencias profesionales, estas se relacionan con competencias académicas y de ellas se llega a los saberes específicos, los cuales se traducen en asignaturas para el plan de estudios.

Las asignaturas resultantes de los saberes específicos se muestran en la Figura 4, donde se expresa la malla curricular del programa de Ingeniería Eléctrica en la Institución Universitaria Pascual Bravo, adaptado al decreto 1295 de 2010 del Ministerio de Educación Nacional y refiriéndose a áreas de formación como lo regula ACOFI, es de destacar que la reforma académica en la actualidad cuenta con aprobación del registro calificado por parte del ministerio de educación nacional, lo cual permite su ofrecimiento por parte de la institución.

Tabla 2: Pertinencia académica de la Ingeniería Eléctrica en Institución universitaria Pascual Bravo.

Pertinencia Social		Pertinencia Académica	
Competencias en el saber hacer profesional		Competencias académicas	Saberes específicos
Diseño e implementación de Sistemas Eléctricos	Diseñar e implementar sistemas de generación de energía eléctrica, sistemas de transporte de energía eléctrica e instalaciones eléctricas industriales, comerciales, residenciales y de alumbrado público, seleccionando sus componentes de acuerdo a las especificaciones de complejidad, confiabilidad y seguridad, cumpliendo en todo momento con las normas de seguridad industrial, medioambientales y las propias del sector.	• Conceptuar los principios físicos involucrados en el funcionamiento y la operación de los sistemas eléctricos. • Realizar el análisis funcional de elementos y componentes mecánicos en los sistemas eléctricos. • Realizar mediciones de las principales variables Eléctricas. • Identificar y calcular las deformaciones y los esfuerzos internos que se producen en elementos de máquinas sometidos a condiciones de carga. • Conocer, interpretar y elaborar planos y diagramas de sistemas eléctricos, de potencia y de control.	• Matemáticas • Ecuaciones diferenciales • Matemáticas especiales • Métodos numéricos • Física mecánica • Física de campos • Electromagnetismo • Cálculo diferencial • Introducción a la tecnología • Herramientas ofimáticas • Herramientas CAD/CAE • Análisis de circuitos • Instalaciones e iluminación • Generación de energía • Transporte de energía • Protecciones y medidas • Redes eléctricas
	Diagnosticar e intervenir el estado de los SE diseñando y ejecutando planes de mantenimiento, para conservar sus condiciones originales de funcionamiento, cumpliendo en todo momento con las normas de seguridad industrial, medioambientales y las propias del sector.	• Diseñar, organizar, administrar, planear y controlar las actividades de mantenimiento en plantas industriales	• Máquinas eléctricas • Mecánica de fluidos • Instrumentación industrial • Gerencia del mantenimiento
Automatización, reconversión y modernización de Sistemas Eléctricos	Optimizar los procesos de generación, transporte y uso de la energía eléctrica mediante la reconversión y modernización de los SE	• Analizar, modelar, diseñar y evaluar componentes y sistemas básicos de generación, transporte y uso de la energía eléctrica	• Gestión del mantenimiento • Análisis de sistemas de potencia • Calidad de la energía • Gestión tecnológica
	Diseñar e implementar proyectos fundamentados en el uso de Energías alternativas	• Analizar, modelar, diseñar y evaluar componentes y sistemas básicos de generación y aprovechamiento de la electricidad a partir de energías alternativas	• Uso racional de la energía
	Diseñar e implementar proyectos de Automatización de SE	• Analizar, modelar, diseñar y evaluar componentes y sistemas básicos de control automático.	• Control • Sistemas automáticos de control
Diseño, gestión y ejecución de proyectos eléctricos	Diseñar, implementar y controlar la ejecución de proyectos de SE	• Seleccionar, calcular, evaluar y ejecutar instalaciones y componentes para SE	• Fundamentos de administración • Gestión empresarial • Ingeniería económica • Evaluación de proyectos
		• Formular, ejecutar, administrar y evaluar proyectos de investigación en el área de la ingeniería	• Metodología de la investigación
	Gestionar y administrar proyectos de uso racional de la energía	• Formular, ejecutar, administrar y evaluar proyectos de investigación en el área de la ingeniería	• Sector energético • Gestión de la calidad • Gestión ambiental

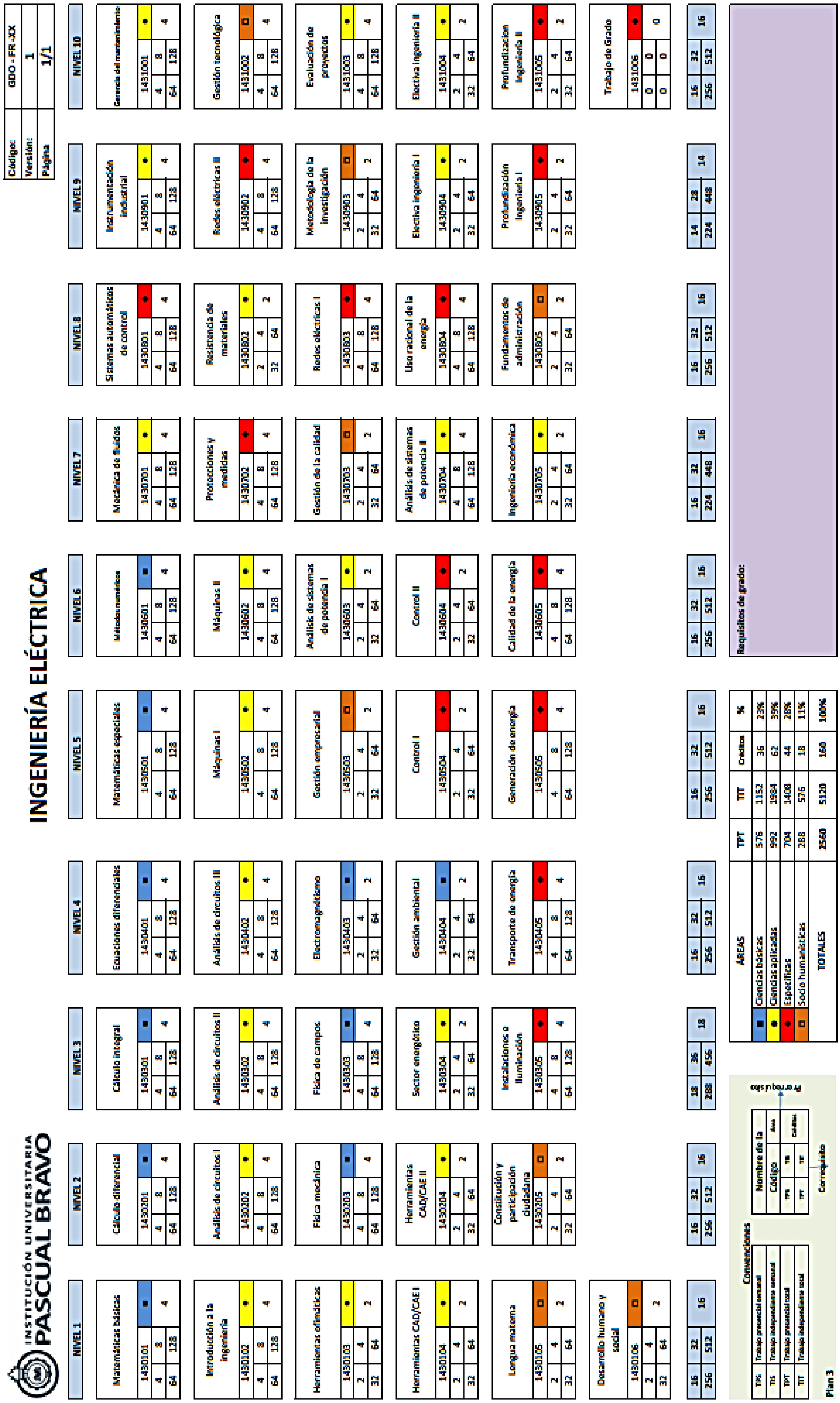

Figura 4: Malla Curricular Ingeniería Eléctrica Institución Universitaria Pascual Bravo

4 Conclusiones

La reforma curricular del programa de Ingeniería Eléctrica en la Institución Universitaria Pascual Bravo a un enfoque por competencias propicia el desarrollo integral del estudiante, ya que promueve la educación continua mediante la cual el estudiante aprende a aprender a lo largo de su vida.

El desarrollo de la educación por competencias es necesaria como aporte en el desarrollo de la Educación Superior en general y en el caso del ingeniero para enfrentar nuevos paradigmas y desafíos, El primer principio de la Ley 30 de 1992, ley que rige la educación superior en Colombia, establece que "la Educación Superior es un proceso permanente que posibilita el desarrollo de las potencialidades del ser humano de una manera integral..";los ajustes realizados al plan de estudios lograron obtener diseños curriculares más cercanos a las nuevas tendencias de la educación superior y, de esa forma, garantizar el cumplimiento del principio.

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Problem Based Learning Applied to the Automatic Control System Course

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Abstract

The growing interdisciplinary in project engineering causes teaching methods as problem-based learning establishes as a necessary complement to the academic training of students. This paper presents the teaching experience in Automatic Control Systems course, which simultaneously develop theoretical knowledge and strategies for solving practical problems, similar to those found in professional practice, achieving encourage students to use self-learning strategies, teamwork and general troubleshooting.

Keywords: active learning; engineering education; project approaches, Automatic control

Enfoque basado en Problemas en la asignatura Sistemas de Control Automático

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Resumen

Dada la creciente interdisciplinaridad de los proyectos de ingeniería, metodologías docentes como el aprendizaje basado en problemas se han consolidado como un complemento necesario en la formación académica de los estudiantes de ingenierías y tecnologías. En este trabajo se presenta y analiza la experiencia docente en la asignatura de Sistemas de Control Automático, la cual permite desarrollar simultáneamente conocimientos teóricos y estrategias para la resolución de problemas prácticos en pequeños grupos, similares a los que se encuentran en la práctica profesional, logrando incentivar a los estudiantes a la utilización de estrategias de autoaprendizaje, el trabajo en equipo y la solución general de problemas.

Palabras claves: Aprendizaje activo; Educación en Ingeniería; Aprendizaje basado en problemas; Proyectos.

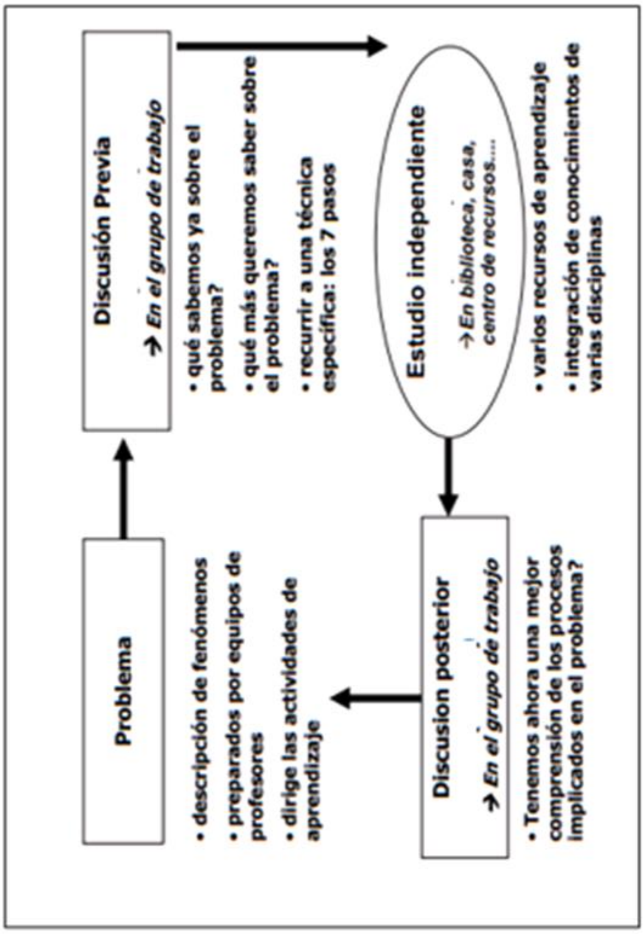
1 Introducción

Una de las metodologías utilizadas para transmitir el conocimiento es conocida como el Aprendizaje Basado en Problemas (ABP), esta metodología propone como punto de partida un problema construido por el profesor el cual permite al estudiante identificar necesidades, comprender mejor el problema/situación e identificar principios que sustentan el conocimiento cumpliendo así objetivos de aprendizaje relacionados con el contenido de la materia (Sebastián, Olanda, & Orduña, 2013).

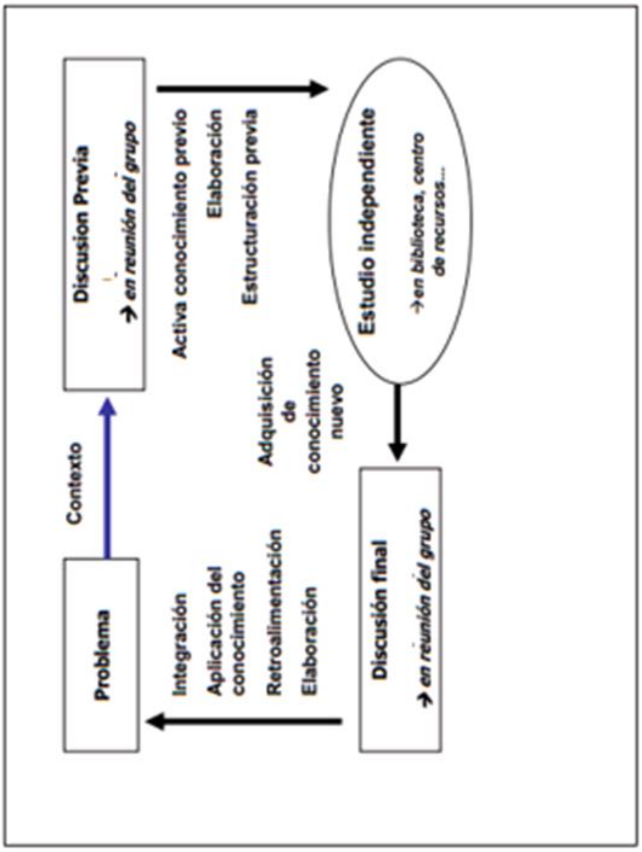
En el ABP el profesor debe según (Benítez, Giraldo, & Domingo, 2014) limitar la complejidad para adaptarla a las posibilidades del alumnado, y tener en cuenta los recursos espaciales, temporales y materiales disponibles así como los objetivos que desean ser alcanzados con la actividad, teniendo en cuenta que un objetivo fundamental de la formación universitaria actual es que los estudiantes aprendan a aprender de forma independiente y sean capaces de adoptar de forma autónoma actitudes críticas que les permitan orientarse en un mundo cambiante fundamentándose en los conocimientos acumulados(Vizcarro & Juárez , 2014).

El proceso del ABP puede diferenciarse en 5 pasos, los cuales son enunciados por (Vizcarro & Juárez , 2014) así: primero se debe orientar el trabajo a construir el conocimiento que hay que poner en práctica, es decir, el conocimiento funcional característico de cada profesión, segundo desarrollar actividades cognitivas necesarias en el campo profesional de referencia (resolución de problemas, toma de decisiones, generación de hipótesis, etc.), como tercer paso desarrollar destrezas de aprendizaje auto dirigido, de cuarto existe la motivación para el aprendizaje, esto se logra si la propuesta de trabajo sitúa a los estudiantes en el contexto de un problema desafiante, que requiera de su participación inmediata y por último el desarrollar la capacidad para trabajar en grupo con los compañeros, lo que implica también otras capacidades como la comunicación, la confrontación constructiva de ideas y puntos de vista o la atención a los procesos del propio grupo.

El proceso del ABP es mostrado en la figura 1, donde se aprecia la secuencia de los pasos esenciales (Figura 1a) para la aplicación de la metodología y la conceptualización del proceso de aprendizaje. (Figura 1b).



a) Proceso del ABP



b) Aprendizaje en el ABP

Figura 1: El proceso del ABP (Vizcarro & Juárez , 2014)

2 Metodología de uso del ABP en la asignatura de Sistemas de Control Automático.

La metodología propuesta se fundamenta en el desarrollo y uso de prototipos y módulos de laboratorio que permitan la implementación de soluciones en automatización y el análisis de los sistemas, proceso llevado a cabo mediante la incorporación del ABP como metodología de enseñanza-aprendizaje.

La automatización es un tópico en el cual confluyen diversas disciplinas de la Ingeniería en la búsqueda de soluciones a problemas en sistemas de control automático se requieren conocimientos diversos como la mecánica, electrónica, electricidad, gestión, economía, entre otras, los cuales deben ser coordinados y estructurados de forma que logren la solución de la situación planteada. La asignatura Sistemas Automáticos de Control es impartida a los estudiantes de la Ingeniería eléctrica en la Institución Universitaria Pascual Bravo, así como a los estudiantes de tecnología Electrónica y sirve como curso electivo para los estudiantes de tecnología en Sistemas Mecatrónicos.

La metodología del ABP es utilizada en los laboratorios de la asignatura, donde se pide al estudiante que idee y diseñe un proceso de automatización, el cual posteriormente debe implementar como proyecto final de la materia. Para llevar a cabo esta actividad se organizan grupos de trabajo de máximo 3 personas. A grandes rasgos la ejecución del proyecto conlleva la elaboración y ejecución de diversas etapas así: 1. Definición del problema a Controlar, 2. Análisis del sistema, 3. Diseño e implementación de la planta o sistema, 4. Diseño de Controladores, 5. Puesta en marcha y comprobación del funcionamiento, 6 Presentación del proyecto en la feria tecnológica de la institución y/o en la muestra robótica y de automatización, 7. Síntesis del proyecto en forma de artículo en formato IEEE, anexando los documentos y esquemas necesarios.

La evaluación, siendo coherentes con la metodología tiene lugar a lo largo de todo el proceso, es decir, durante toda la realización del proyecto y la finalización del mismo; lo evaluado son los contenidos incluidos en los problemas con los que se trabajó recurriendo a una variedad de procedimientos como exámenes escritos y prácticos, mapas conceptuales, evaluación de pares, evaluación del tutor, presentaciones orales e informes escritos; pudiendo lograr una evaluación heterogénea donde participa el estudiante, el docente, el grupo y pares académicos.

3 Resultados

El uso del ABP en la asignatura de Sistemas Automáticos de Control ha mostrado mejora en aspectos del proceso de enseñanza y aprendizaje tales como el desarrollo de habilidades de autoaprendizaje, la adquisición de estrategias generales de solución de problemas, mejoras en la selección y aumento en el uso de materiales como libros, fotocopias, internet, entre otros con mayor autonomía, aprendizaje de habilidades sociales y personales mediante el trabajo en grupos, mejor comprensión, integración y uso de lo aprendido, familiarización e implicación del alumno en situaciones de su práctica profesional.

La aplicación de la metodología del ABP promueve un procesamiento estratégico y permite el recuerdo de la información a mediano y largo plazo, fomenta la capacidad de solución de problemas de diferente naturaleza y estimula una actitud activa hacia la exploración y la indagación, además, por su carácter multidisciplinar permite la integración de conocimientos de diferentes campos, en la Figura 2 se muestran imágenes de diferentes etapas del proceso del ABP en proyectos realizados y presentados por los estudiantes de la asignatura Sistemas Automáticos de Control.

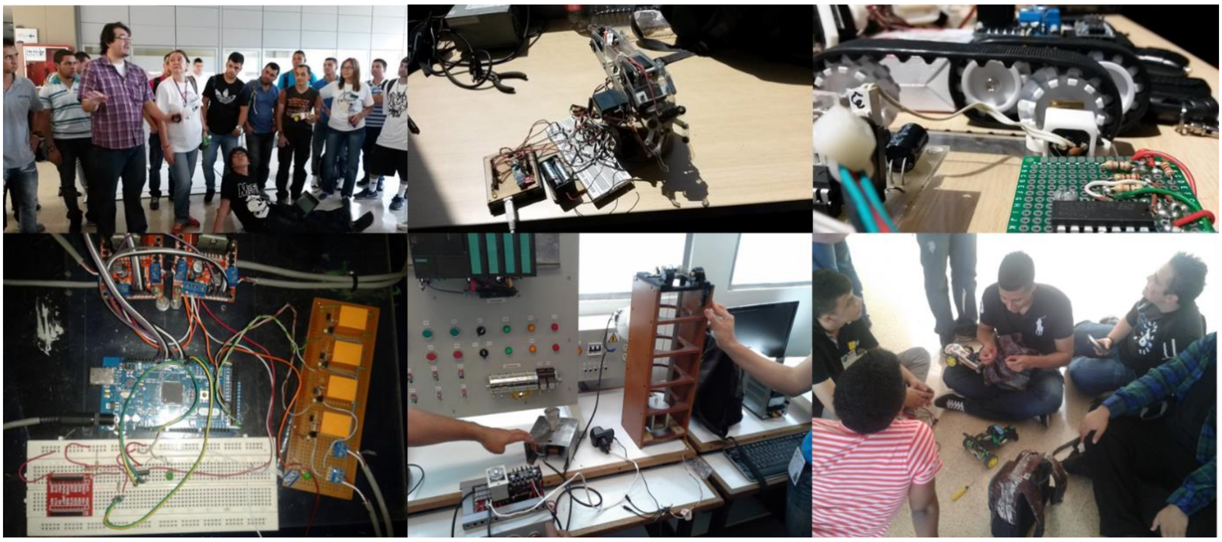


Figura 2: Proyectos estudiantes en diferentes etapas del ABP

Existen casos donde los proyectos no solo se exponen en la feria tecnológica y en la muestra robótica y de automatización de la institución, sino que se ha participado en eventos nacionales e internacionales como lo son campus Party (Figura 3) y el salón de inventores (Figura 4) por mencionar algunos.

Figura 3: Participación Campus Party

Figura 4: Participación IV y V salón de inventores

4 Conclusion

El uso del ABP en la asignatura Sistemas Automáticos de control resulta de gran utilidad para fomentar aspectos como el trabajo en equipo, gestión de recursos y materiales en proyectos técnicos, desencadenando hasta la fecha experiencias positivas para los docentes, alumnos y la Institución Universitaria Pascual Bravo en general.

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Predictive and agile´s management tools used by teaching at Project´s subject

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Abstract

Habitually, the project managers meet obliged to choose between an agile management or a predictive management of his projects and, in many cases, it has managed to affirm that the second one has managed to substitute completely the first one. Nevertheless, very few ones know the potential that offers the combination between both systems, for what this educational experience will try to demonstrate the benefits derived from the above mentioned combination. In the initial phases of project management there is fundamental the definition of the requirements of the project. We solve this applying the predictive methodologies since that of PMI is (Project Management Institute), concretely in the Area of Knowledge of Management of the Scope. It is, in these phases, where the use combined of predictive and agile methodologies, it turns into a key factor of success of the project. The educational offer materializes with the use, in the initial phase and of definition of the life cycle of the Project, of two management tools of agile projects: Business Model Canvas (BMP), as tool of creation of a model of business and the Project Model Canvas (PMC) that helps to transform the idea of business into a Project plan, as information of entry to later develop the Record of Constitution of the project, necessary to enter the Phase of planning of the project with the previous definition of Work breakdown structure (WBS) and later planning. The symbiosis of agile and predictive methodologies beginning for the agile ones to focus and to obtain the general definition of the project it helps to avoid mistakes in the following stages of the life cycle of the project

Keywords: Predictive management of projects; agile Management of projects; Business Model Canvas; Project Model Canvas; PMI

Herramientas de gestión de proyectos ágiles y predictivas en la docencia de la materia de Proyectos

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Abstract

Habitualmente, los gestores de proyectos se ven obligados a elegir entre una gestión ágil o una gestión predictiva de sus proyectos y, en muchos casos, se ha llegado a afirmar que la segunda ha conseguido sustituir por completo a la primera. Sin embargo, muy pocos conocen el potencial que ofrece la combinación entre ambos sistemas, por lo que esta experiencia docente tratará de demostrar los beneficios derivados de dicha combinación. En las fases iniciales de gestión de proyectos es fundamental la definición de los requisitos del proyecto. Esto lo resolvemos aplicando las metodologías predictivas como es la de PMI (Project Management Institute), concretamente en el Área de Conocimiento de Gestión de la Integración y posteriormente en la de Gestión del Alcance. Es, en estas fases, donde el uso combinado de metodologías predictivas y ágiles se convierte en un factor clave de éxito del proyecto. La propuesta docente se materializa con el uso, en la fase inicial y de definición del ciclo de vida del Proyecto, de dos herramientas de gestión de proyectos ágiles: Business Model Canvas (BMP), como herramienta de creación de un modelo de negocio y el Project Model Canvas (PMC) que ayuda a transformar la idea de negocio en un Plan de Proyecto, como datos de entrada para posteriormente desarrollar el Acta de Constitución del proyecto, necesaria para entrar en la Fase de planificación del proyecto con la definición previa de la Estructura de desglose del trabajo (EDT) y posterior planificación. La simbiosis de metodologías ágiles y predictivas empezando por las ágiles para enfocar y obtener la definición general del proyecto ayuda a evitar errores en las siguientes etapas del ciclo de vida del proyecto

Keywords: Gestión de proyectos predictiva; Gestión de proyectos ágil; Business Model Canvas; Project Model Canvas; PMI

1 Introducción

La Gestión de Proyectos es una de las actividades clave que lleva la mayor responsabilidad dentro de la empresa. Una empresa que vive creando, planificando y desarrollando proyecto, quiere decir que es una empresa que está en vanguardia de los cambios continuos e imparables de la globalización actual. Es una entidad que está en constante cambio interno y crecimiento gradual y sostenible. La gran importancia de la gestión de Proyectos garantiza la adecuada distribución y control del presupuesto, realizando en tiempo cada fase del proyecto reduciendo y controlando los costos, detectando y anticipándose a los posibles problemas e inconvenientes que puedan surgir en la marcha. Esta forma de trabajar por proyectos es necesario ir transmitiéndosela al alumno con el fin de que adquiera estas competencias en su curriculum vitae y sea capaz en su futuro de tener un entrenamiento sobre la Gestión de Proyecto que va a tener que utilizar en el mundo laboral. En la actualidad existen dos tipos de metodologías en la dirección de proyectos: predictivas y ágiles. Se utilizan unas u otras dependiendo del tipo de Proyecto. Las metodologías predictivas definen el alcance del proyecto, el tiempo y el coste en las fases tempranas del ciclo de vida del proyecto, en cambio los métodos ágiles aplicados a la adquisición y definición de los requisitos del Cliente es una forma innovadora de conseguir hacer llegar tu valor al cliente, Bose (2008). Son metodologías de ciclo de vida y adaptativo. Se utilizan sobre todo en entornos cambiantes. Cuando los requisitos y el alcance son difíciles de definir con antelación, Trivedi (2013).

2 Objetivo

El objetivo de este trabajo se basa en la definición de un proyecto y su alcance (propuesto por el grupo de trabajos de alumnos) mediante la combinación de herramientas ágiles y herramientas predictivas. Se tratan de dos tipos de herramientas sensiblemente distintas, que escasamente se combinan debido a sus diferentes características pero que, como se espera demostrar en este proyecto, poseen un gran potencial como resultado de su correcta aplicación conjunta. Por tanto, y a modo de resumen, se realizará una división de la fase de inicio del ciclo de vida de un proyecto en tres partes, identificado en cada caso el objetivo concreto que se desea alcanzar. Las dos primeras partes se apoyarán en herramientas ágiles, mientras que la última se desarrollará a partir de una herramienta predictiva.

En primer lugar se llevará a cabo la creación de un modelo de negocio concreto, mediante el empleo de la herramienta ágil "Business Model Canvas". Se trata de un método simple de establecer modelos de negocio, basado en el empleo de un gráfico o "lienzo" dividido en nueve secciones, que abarcan desde la propuesta de valor y los recursos necesarios, hasta las relaciones que se establecerán con los clientes. De este modo, se pretende simplificar al máximo la generación de ideas, sacando el máximo partido posible a la distribución de dicho gráfico. Se trata, por tanto, de una herramienta sencilla pero útil, que trata de estimular la creación de ideas mediante la relación visual existente entre las secciones que componen el "lienzo". En nuestro caso, esta herramienta determinará el marco general, o entorno, sobre el que se constituirá el proyecto; generando la base de partida sobre la que más tarde se profundizará.

Una vez determinadas las ideas clave del modelo de negocio, será necesario profundizar en ellas, seleccionando un proyecto concreto que pueda dar solución a alguno de los problemas observados o explotar algún punto concreto en busca de mayores beneficios. En esto consiste la segunda fase del proyecto, para la cual se empleará la herramienta ágil "Project Model Canvas". Así, los factores clave comenzarán a relacionarse entre sí originando la estructura del proyecto que se desea llevar a cabo; apoyándose nuevamente en un gráfico sencillo que estimule la generación de nuevas ideas, así como la relación entre las mismas. En cierto modo, podemos considerar esta fase como un nexo entre el marco o entorno inicial y la última de las fases.

Finalmente, y como última parte de la fase de inicio del Proyecto, se desarrolla el Acta de Constitución del Proyecto, que marca el punto de arranque del Proyecto, en donde el Patronizador (executive sponsor) autoriza formalmente la existencia del proyecto y confiere al director del proyecto la autoridad para asignar los recursos de la organización a las actividades del proyecto.

Esta Acta de Constitución será el entregable necesario de la Fase de inicio del proyecto para poder comenzar la segunda fase del ciclo de vida del proyecto: la planificación del mismo. Así posteriormente entrar en dentro de esta fase de planificación en la que se llevará a cabo la planificación detallada, la implantación y la gestión del proyecto seleccionado mediante la metodología predictiva PMI (Project Management Institute). Así, actuando sobre el marco y el nexo previamente establecidos en las fases anteriores, se seguirán los estándares y fundamentos recogidos en el PMBok, reconocidos como buenas prácticas para la gestión de proyectos. Por tanto, puede observarse una perfecta sincronía entre las tres etapas de la primera fase de inicio del proyecto y su vinculación posterior con la fase de planificación en la que se define el alcance del proyecto a través de la Estructura de desglose del trabajo (EDT)

3 Ciclo de vida del Proyecto (CVP)

El ciclo de vida de un proyecto es la serie de fases por las que atraviesa un proyecto desde su inicio hasta su cierre (PMI, 2013) .Las fases se pueden dividir en partes, resultados o entregables intermedios, hitos específicos dentro del alcance global del trabajo. Las fases son generalmente acotadas en el tiempo, con un inicio y un final o punto de control. Cada proyecto tiene un inicio y un final definidos, los entregables específicos y las actividades que se llevan a cabo variarán ampliamente dependiendo del proyecto. El ciclo de vida proporciona el marco de referencia básico para dirigir el proyecto. Los enfoques de los ciclos de vida de los proyectos pueden variar continuamente desde enfoques predictivos u orientados a plan hasta enfoques adaptativos u orientados al cambio, como hablamos anteriormente. En un ciclo de vida predictivo, el producto y los entregables se definen al comienzo del proyecto y cualquier cambio en el alcance es cuidadosamente gestionado. En un ciclo de vida adaptativo, el producto se desarrolla tras múltiples iteraciones y el alcance detallado para cada iteración se define solamente en el comienzo de la misma.

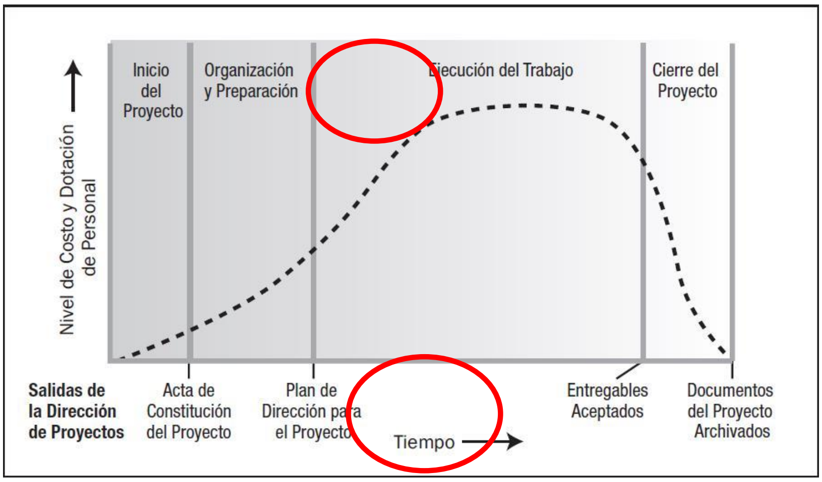

Figura 1: Ciclo de Vida del Proyecto. Fuente PMBOK@

Este trabajo se centra inicialmente en la Fase de Inicio del proyecto (figura 1) donde utilizamos como entregable final el desarrollo del Acta de Constitución del Proyecto, herramienta utilizada en las metodologías predictivas, para dar paso a la Planificación del proyecto, en la que utilizaremos otra herramienta predictiva: la estructura del desglose del trabajo (EDT)

Según la metodología predictiva PMI@, en esta fase de inicio es necesario tener en cuenta dos áreas de conocimiento: la gestión de la integración y la gestión de los stakeholders o interesados del proyecto. Es en este entregable final (acta de constitución) donde quedan bien definidos el inicio y los límites del proyecto. La creación de este registro formal del proyecto es clave para el éxito del proyecto. En la figura 2 se describen los datos de entrada, herramientas utilizadas y datos de salida necesarios a tener en cuenta en el proceso de desarrollo del Acta de constitución del equipo. Fuente PMBOK@, 2013

Figura 2: Proceso de Desarrollo del Acta de Constitución Proyecto. Fuente PMBOK@

Como se puede apreciar en la figura 2, como datos de entrada necesitamos el "Enunciado del trabajo del proyecto" y "el Caso de Negocio". Para llegar a él, nos hemos basado en la utilización de dos herramientas ágiles: el Business Model Canvas (BMC) y el Project Model Canvas (PMC)

3.1 Business Model Canvas

En 2010 Alex Osterwalder diseño el Business Model Canvas; un formato en forma de lienzo que visualiza un modelo de negocio abarcándolos las cuatro áreas principales de un negocio: cliente, oferta, infraestructura y viabilidad económica. Es una herramienta que utiliza un lenguaje común para describir, visualizar, evaluar y modificar modelos de negocio. Permite fácilmente describir y gestionar modelos de negocio con el fin de desarrollar nuevas alternativas estratégicas. Describir el modelo de negocio en nueve módulos básicos, que refleja la lógica que sigue una empresa para conseguir ingresos.

Este modelo de negocio es un anteproyecto de una estrategia que se aplicará a la empresa (en las estructuras, procesos y sistemas de una empresa) para tener éxito. Además su definición nos aporta un dato de entrada necesario en el proceso de desarrollo del Acta de Constitución del Proyecto (herramienta predictiva). El valor que estos nueve campos nos dan en sólo una hoja, resultan un documento que ofrece directamente una visión global "helicopter view" de la idea de negocio, mostrando claramente las interconexiones entre los diferentes elementos. Figura 3.

Con esta herramienta, se definen en el séptimo paso, las actividades claves o proyectos necesarios para llevar acabo el negocio. Utilizando técnicas de selección múltiple de proyectos a través de estudios viabilidad económica (Valor actual Neto, Tasa retorno inversión.,...) seleccionamos aquel primer proyecto con el que nos conviene empezar. Este proyecto lo desarrollaremos con otra metodología ágil: el Project Model Canvas.

3.2 Project Model Canvas

Es una herramienta ágil de Gestión de Proyectos creado por el profesor Finocchio (2012) basándose en la neurociencia, la teoría de Design thinking y en el Modelo de Negocio Canvas en el año 2012. Resuelve el problema de gestión de información y gestión de los interesados .Se centra en el alma del Proyecto y permite que los stakeholders e incluso el cliente participe en la elaboración del proyecto. Es una metodología que tiene en cuenta 13 pasos para elaborar un plan de proyecto. Ayuda a elaborar un prototipo del modelo mental del proyecto y ver las relaciones e interdependencias entre cada parte del proyecto. Con estas fases resolvemos las siguientes preguntas: en los tres primeros paso resolvemos el por qué hacemos el proyecto (justificación, objetivo, beneficios), en los dos siguientes resolvemos la pregunta qué hacemos (producto y requisitos), a continuación en los 2 siguientes quién lo realiza (stakeholders, y el equipo), dando paso luego a cómo lo vamos a realizar (entregables, restricciones y riesgos) y finalmente tratamos cuándo y cuánto nos va a costar (presupuesto y línea del tiempo.

3.3 Estructura de Desglose del Trabajo (EDT)

Es una herramienta predictiva utilizada en la fase de planificación del proyecto. Es una descomposición jerárquica del alcance total del trabajo a realizar por el equipo del proyecto para cumplir con los objetivos del proyecto y crear los entregables requeridos. Para realizarla hay que tener claro inicialmente el objetivo y los límites del proyecto, previamente definido con la herramienta ágil Project Model Canvas.

4 Caso práctico. Aplicación de metodologías ágiles y predictivas en la selección y definición de Proyectos en el aula

La Escuela de Ingeniería Industrial de la Universidad de Vigo está experimentando en la actualidad un Proyecto Piloto de educación multidisciplinar entre diversos grados universitarios. En concreto Grado de Biología, Grado de Ingeniería y grado de Filología. Esta idea parte de la Escuela de Ingeniería y gracias a la colaboración de diversos profesores y facultades de la Universidad de Vigo.

Basándonos en la metodología de Enseñanza basada en Proyectos (PBL), Lima (2012), que desde varios años se viene implantando en la docencia asignada al Área de Proyectos, se ha dado un paso más y se pretende realizar una experiencia multidisciplinar entre carreras distintas orientada por un grupo de profesores "Team Teaching" Aquere (2012), también multidisciplinar, intentando en todo momento acercarnos a la realidad del mundo empresarial y que de esta forma los alumnos adquieren unas determinadas competencias, Campos, (2012). Tras analizar las competencias Básicas, generales, específicas y transversales de ambas carreras, hemos seleccionado aquellas que en común tienen que adquirir los equipos multidisciplinares de proyectos y que definimos a continuación en la tabla 1 y 2. En esta tabla se definen además la forma de adquisición de la competencia.

Tabla 1. Competencias Específicas

Competencias Específicas	Adquisición de la competencia
Obtener información, desarrollar proyectos e interpretar resultados	Realizar investigación documental en equipo en diversas fuentes. Desarrollar un Proyecto. Adoptar soluciones y análisis de resultados en el Proyecto
Participar en la dirección, redacción y ejecución de proyectos	Realizar trabajo en grupo sobre un tema propuesto y/o presentado por ellos

Familiarizarse con procesos de asesoramiento y peritaje sobre algunos de los aspectos relacionados con la biología	Emplear casos prácticos para familiarizarse con los aspectos científicos-tecnológicos, éticos, legales y socioeconómicos en la labor de asesoramiento y peritaje
Conocer y manejar la metodología, la instrumentación científico-técnica propias de los proyectos	Definir los requisitos científico-tecnológicos, éticos, legales y socioeconómicos del proyecto

Tabla 2. Competencias Transversales

Competencias Transversales	Adquisición de la competencia
Desarrollar la capacidad de análisis y síntesis	Desarrollar un abstract gráfico del Proyecto
Adquirir la capacidad de organizar y planificar las tareas y el tiempo	Realizar una planificación del proyecto a través de diagramas Gantt
Desarrollar habilidades de comunicación oral y escrita	Realizar seminario de preparación y exposición oral y escrita del proyecto.
Emplear recursos informáticos relativos al ámbito de estudio	Realizar prácticas informáticas con herramientas de gestión de proyectos.
Saber buscar e interpretar información procedente de fuentes diversas	Realizar investigación documental en grupo en diversas fuentes. Seleccionar la propuesta más afín al Proyecto
Resolver problemas y tomar decisiones de forma efectiva	Adoptar una solución única al proyecto en los seminarios de control
Trabajar en colaboración o formando equipos de carácter interdisciplinar	Realizar trabajo en grupo de tipo multidisciplinar entre distintos ámbitos de conocimiento
Desarrollar el razonamiento crítico	Adoptar una solución única al proyecto en los seminarios de control
Adquirir un compromiso ético con la sociedad y la profesión	Elaborar el Proyecto manteniendo un respeto al entorno en el que se desarrolle
Adquirir habilidades en las relaciones interpersonales	Utilizar técnicas de trabajo en grupo. Roles del equipo de trabajo.
Desarrollar la creatividad, la iniciativa y el espíritu emprendedor	Desarrollar un Proyecto que represente una solución original al proyecto planteado
Asumir un compromiso con la calidad	Utilizar herramientas de calidad en la gestión de Proyectos
Desarrollar la capacidad de autocrítica	Evaluar el trabajo individual y en grupo mediante una rúbrica
Desarrollar la capacidad de negociación	Utilizar técnicas de trabajo en grupo.

4.1 Ejemplo de aplicación de un grupo de trabajo

Los grupos de trabajo multidisciplinar serán constituido por 6 alumnos pertenecientes al último curso de grado, 4º curso-2º cuatrimestre, previo a la realización de la fase de realización de los Trabajos Fin de Grado. La materia que cursan es de6 créditos con una distribución del 35% del tiempo en calases presenciales y el 65% trabajo de alumno tutorizado. Cada grupo estará constituido por 3 alumnos de biología, 2 de ingeniería y 1 de filología. En total se han constituido 22 grupos de alumnos. Dentro de los requisitos para los temas propuestos de Proyectos es que el Tema de Proyecto o Pitch, tenga contenido en temas de biología y contenido en alguna de las ramas de ingeniería. El alumno de filología se encargará de la corrección de las memorias y documentación del proyecto, de forma continua.

Analizando uno de los grupos de trabajo, se presentan a continuación las siguientes figuras en las que se aprecia el avance del Proyecto, en el siguiente orden:

Fase Inicio Proyecto

Figura 3 - Business Model Canvas

Figura 4 - Project Model Canvas

Figura 5 - Acta de Constitución

Fase Planificación proyecto

Figura 6 - Estructura Desglose del Trabajo

Figura 7 - Planificación del proyecto

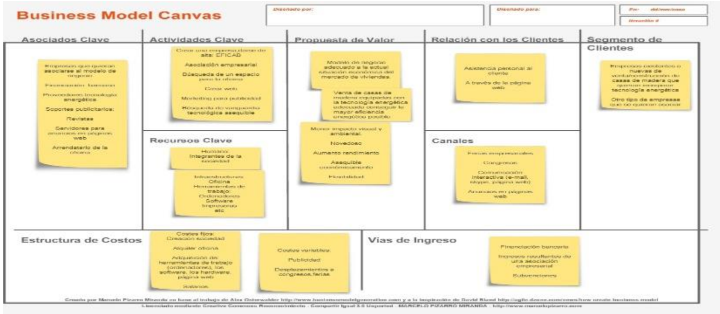

Figura 3: Ejemplo del Business Model Canvas (BMC)

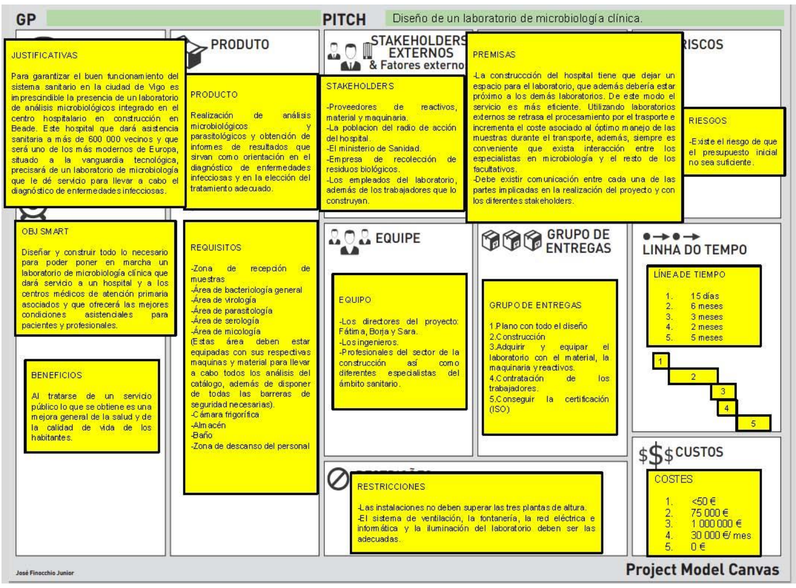

Figura 4: Ejemplo del Project Model Canvas (BMC)

PMI Registered Education Provider — Project Management Institute

FGPR010- Versión 4.0

CONTROL DE VERSIONES					
Versión	*Hecha por*	*Revisada por*	*Aprobada por*	*Fecha*	*Motivo*
0.1	GRUPO 1Lunes	GRUPO 1Lunes	Director del proyecto	13/10/2014	Version Original
0.2					
0.3					

PROJECT CHARTER

NOMBRE DEL PROYECTO	SIGLAS DEL PROYECTO
Línea de Embotellado de Agua y su Distribución al cliente	LEADC

DESCRIPCIÓN DEL PROYECTO: *¿QUÉ, QUIÉN, CÓMO, CUÁNDO Y DÓNDE?*

El proyecto "Línea de embotellado de agua y distribución al cliente", consiste en la creación de una planta embotelladora de agua obtenida directamente del sistema de suministro urbano. La implementación se realizará en la ciudad de Nueva York debido a la alta calidad de su agua y a la potencialidad del mercado allí existente. Paralelamente se desarrollará el sistema logístico de distribución del producto.

La implementación ayudara en :

- Mayor accesibilidad a agua embotellada a un precio atractivo.
- Creación de un sistema de distribución sostenible a la vez que eficiente y con un bajo impacto medioambiental.

El desarrollo del proyecto estará a cargo de:

- Axel Manuel Boubeta Refojos -- Director del Proyecto
- Román Amaro Pintos -- Encargado de la fase de producción
- Rocío Dorado Álvarez -- Encargada de la fase de diseño y logística
- Roberto María Rosati -- Encargado de Marketing y función Comercial (relación con proveedores y clientes)

El proyecto se realizará desde el de 20 de octubre de 2014 hasta 18 de Agosto del 2015, donde la ejecución del proyecto se llevará a cabo en **Walker Street (Nueva York)**, y el diseño de las fases del proyecto tendrá como sede la **Escuela Oficial de Ingenieros Industriales** de la **Universidad de Columbia**.

DEFINICIÓN DEL PRODUCTO DEL PROYECTO: *DESCRIPCIÓN DEL PRODUCTO, SERVICIO O CAPACIDAD A GENERAR*

Figura 5: Ejemplo de Acta de Constitución del Proyecto

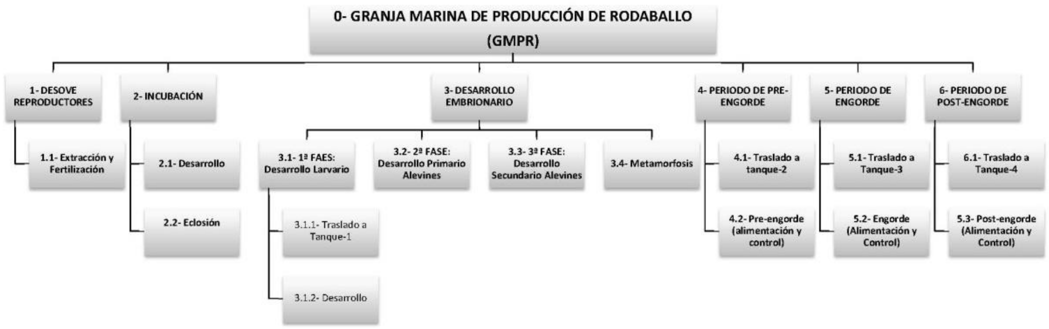

Figura 6: Ejemplo de la Estructura de Desglose del trabajo (EDT)

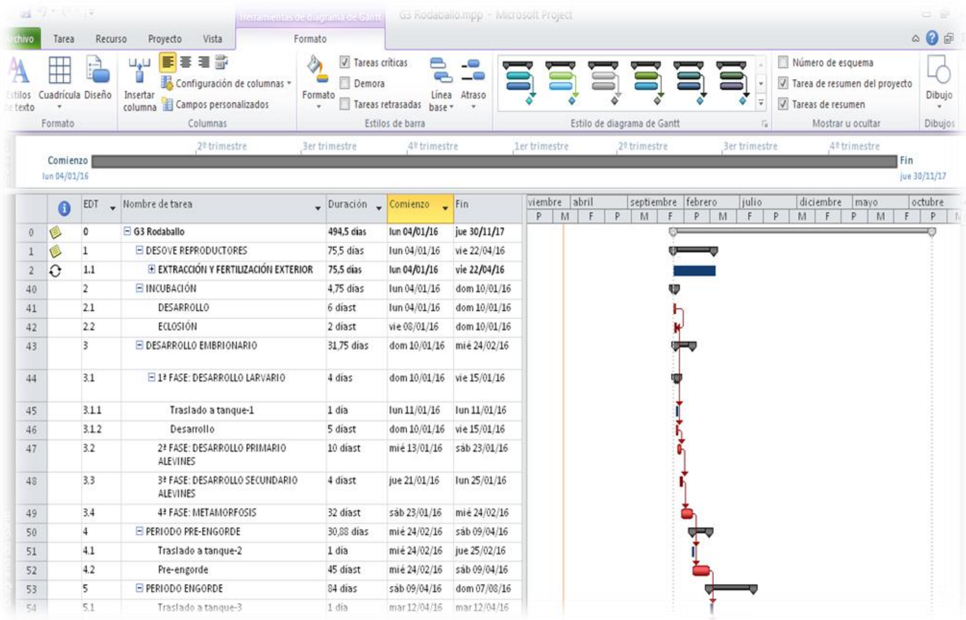

Figura 7: Ejemplo de Planificación del proyecto

5 Conclusiones

El uso de metodologías activas, como es la enseñanza basada en proyectos permite el desarrollo de habilidades profesionales vitales en el actual mundo laboral: aprendizaje continuo, autonomía, grupos de trabajo, espíritu crítico, habilidades de comunicación y planificación. El alumno asume responsabilidad y por otro lado libertad de acción. El proyecto-ejercicio que cumple con las características de un PBL debe ser relevante, con objetivos y etapas claras, complejo en el sentido de tener distintas posibles soluciones e interdisciplinar. Estas características son las mismas con las que se van a encontrar en los proyectos reales.

La primera parte de la materia se centra en establecer en los grupos como objetivo el plan de Trabajo del proyecto y los objetivos a conseguir junto con sus entregables. Así mismo realizan una exposición pública del trabajo en un auditorio durante un tiempo predeterminado, lo que les lleva a desarrollar su capacidad de comunicación y síntesis.

El rol del profesor es de facilitador, aporta conocimientos básicos iniciales que luego los alumnos desarrollan en su trabajo. Desempeñan además el papel de Cliente en la exposición de los trabajos. Además evaluarán críticamente los documentos entregados, las presentaciones públicas y el funcionamiento de los equipos. Tutorizan los diferentes proyectos dentro de los grupos, facilitando el aprendizaje y ayudándoles a encontrar sus propias soluciones.

Entre las ventajas conseguidas se encuentra:

- Los métodos ágiles permiten ver de una forma más flexible y modular el proceso de diseño de un proyecto
- Se incrementa la participación de los alumnos en la toma de decisiones
- Ayuda a mejorar la calidad de las metodologías docentes y facilita la utilización de herramientas actuales y útiles
- La simbiosis de metodologías ágiles y predictivas empezando por las ágiles para enfocar y obtener la definición general del proyecto ayuda a evitar errores en las siguientes etapas.
- La gestión de proyectos no es sencilla, y cada vez más tenemos que ser adaptativos ante los clientes, realizar continuos cambios en los proyectos, en definitiva una combinación de las metodologías de gestión de proyectos predictivas con las ágiles es la mejor solución para adaptarse a los continuos cambios en los proyectos

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IJCLEE/PAEE'2015 Poster Submissions

Submissions accepted for IJCLEE/PAEE'2015 poster session in English, Portuguese and Spanish.

Use of PBL in an organizational setting construction: discussion focusing on issues related to projects

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Abstract

The changes in the scenario of civil engineering and consequently the production management of the works require an engineer with a different player profile works, resulting in the need for more refined skills of these professionals, become indispensable dominance over innovation, customer focus, planning, knowledge of quality management systems, sustainability and a humanist vision. The main objective of this paper is to show the efficiency of the use of the methodology of Problem Based Learning adapted to the organizational context. The research strategy was adopted action research as it had teamwork and commitment to change on the part of those involved, for this research has focused on issues related to projects, supplies and human resources. Achievements involved the development related to the organizational context, the individual, collective and organizational learning skills, pointing out problems and possible solutions in the management company. Through the development of managerial skills, was stimulated a humanistic, sustainable vision, customer focus, and a better system of quality management. We identified problems in organizational management system, evidencing the need for creating an enabling environment for the exchange of information among its sectors.

Keywords: Problem-Based Learning; skills; organizational management; building.

Utilização da metodologia ABP em um ambiente organizacional da construção civil: discussão com foco em problemas relacionados a projetos

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Resumo

As mudanças no cenário da construção civil e consequentemente da gestão da produção das obras exigem um engenheiro com perfil diferente, resultando na necessidade de novas competências, relacionadas a inovação, foco no cliente, planejamento e controle, sistemas de gestão da qualidade, sustentabilidade e visão humanista. O objetivo principal desta pesquisa foi desenvolver as competências gerenciais dos engenheiros civis gestores de obra de uma empresa construtora com o uso do método da Aprendizagem Baseada em Problemas adaptado ao contexto organizacional. A estratégia de pesquisa adotada foi a pesquisa-ação, na qual a equipe de pesquisa atua com profissionais para melhorar a forma como estes entendem e resolvem problemas, para esta pesquisa, focou-se nos problemas relacionados a questões específicas sobre projetos. Os resultados alcançados envolveram o desenvolvimento de competências relacionadas ao contexto organizacional, à aprendizagem individual, coletiva e organizacional, apontando problemas e possíveis soluções de gestão na empresa. Com o desenvolvimento de competências gerenciais, foi estimulada uma visão humanística, sustentável, com foco no cliente, além de um melhor sistema de gestão da qualidade. além disso, identificaram-se problemas no sistema de gestão organizacional da empresa, ficando evidente a necessidade da criação de um ambiente propício para troca de informações entre seus diferentes setores.

Palavras-Chave: Aprendizagem Baseada em Problemas; competências; gestão organizacional; construção civil, projetos.

1 Introducão

A crescente e constante mudança da competitividade no ramo da construção civil, a velocidade com que novas tecnologias vêm sendo disponibilizadas, a quantidade e o acesso rápido à informação caracterizam um ambiente turbulento, que requer uma grande capacidade de adaptação e aprendizagem nas organizações, o que resulta em uma alteração constante no perfil dos engenheiros civis gestores de obra.

De acordo com esse contexto, a ênfase em uma formação abrangente e a ampliação das possibilidades de experiência prática durante o curso superior são avaliadas como alternativas para atender à exigência de um perfil multiprofissional e proporcionar a maturidade pessoal e a identidade profissional necessárias para agir em situação de imprevisibilidade, realidade a que estão sujeitas as organizações atuais. Além disso, o investimento no desenvolvimento de competências gerenciais torna-se indispensável para empresas que pretendam se manter competitivas no mercado atual.

O artigo objetivou mostrar a eficiência no uso da metodologia da Aprendizagem Baseada em Problemas adaptado ao contexto organizacional com o foco na resolução de problemas relacionados a projetos no ambiente organizacional da construção civil. A pesquisa foi proposta à empresa estudada, pois a mesma passava por um processo de realocação de funções entre seus engenheiros civis, gestores de obra. O método da Aprendizagem Baseada em Problemas adaptado ao contexto organizacional foi utilizado para potencializar o desenvolvimento das competências gerenciais de tais profissionais.

Bomfim (2012) diz que o desenvolvimento de competências gerenciais nas organizações permite um avanço para o desenvolvimento do conhecimento, das habilidades e atitudes dos profissionais na busca da qualidade e produtividade no ambiente de trabalho. Este estudo auxilia na compreensão da importância do desenvolvimento de competências gerenciais na construção civil, seguindo a estratégia metodológica da pesquisa-ação.

2 Referencial Teórico

2.1 Aprendizagem Baseada em Problemas adaptado ao contexto organizacional

Kalatzis (2008) afirma que as origens históricas do método ABP, originalmente do inglês Problem Based Learning (PBL), na sociedade atual, têm início no século XX. Conforme Schmidt (1993), na década de 1920, o PBL foi utilizado como método de estudos de casos nos cursos de direito da Universidade de Harvard, nos Estados Unidos.

Barrows e Tamblyn (1976) conceituam a ABP como a aprendizagem que resulta do processo de trabalho orientado para a compreensão ou resolução de um problema. Segundo Schmidt (1993), é uma abordagem para a aprendizagem e a instrução, na qual os estudantes lidam com problemas em pequenos grupos, sob a supervisão de um tutor.

Mamede et al. (2001), por sua vez, conceituam ABP de forma mais ampla, como uma estratégia educacional e uma filosofia curricular, concebendo um processo de aprendizagem no qual os estudantes autodirigidos constroem ativamente seus conhecimentos. Partindo de problemas e trabalhando de maneira colaborativa, os alunos aprendem de forma contextualizada, formulam seus próprios objetivos de aprendizagem e apropriam-se de um saber que adquire um significado pessoal, segundo as disposições internas de cada um.

Kalatziz (2008) diz que a ABP, por ser um modelo instrucional, apresenta definições, características e objetivos próprios que o configuram como um método. O mesmo autor diz que a ABP consiste em um método instrucional que faz uso de problemas da vida real, servindo de estímulo para o desenvolvimento do pensamento crítico, de habilidades de resolução de problemas e da aprendizagem dos conceitos que integram o conteúdo programático.

A ABP é vista como um método que dá ênfase ao desenvolvimento de habilidades essenciais como a análise efetiva do problema (Barrows; Tamblyn, 1976; Woods, 1996; Engel, 1997) e o estudo autodirecionado. A abordagem centrada no aluno também desenvolve a habilidade de escutar, a de resumir as informações e a de ensinar os outros (Barrows; Tamblyn, 1976). Ensinar os colegas é uma habilidade requerida pela maioria dos profissionais, juntamente com a habilidade de trabalhar como parte de uma equipe (Barrows; Tamblyn, 1976; Woods, 1996).

O modelo adaptado, utilizado neste artigo, foi desenvolvido por Neves (2006) em sua tese de doutorado, em que o autor diz que o processo de aprendizagem inicia-se com o compartilhamento do conhecimento individual. Em seguida, a aprendizagem torna-se um processo social, partilhado pelas pessoas do grupo, gerando aprendizagem não só individual como também grupal. Depois da compreensão e da busca da solução para o problema, compartilhada pelo grupo, discutem-se novamente os resultados com outros membros da empresa, motivando a proposição final para a solução do problema em forma de regras e procedimentos, o que cria condições favoráveis para a aprendizagem organizacional.

A utilização da ABP adaptada ao contexto organizacional justifica-se pelo fato de a empresa estudada querer investir na capacitação de seus engenheiros gestores de obra o mais próximo de seu contexto de atuação, ou seja, em seu próprio ambiente de trabalho, compartilhando as experiências entre si, de modo que eles possam discutir a forma como executam suas atividades. Assim, eles podem identificar os conceitos discutidos e relacioná-los à realidade da organização.

O modelo é dividido em cindo etapas: problematização, ação, discussão de solução, planejamento da apresentação da solução e consolidação. O processo inicia-se pela análise detalhada da situação, na qual se define o problema e se estabelecem as proposições iniciais para sua solução. Na etapa seguinte, individualmente, aplica-se a solução na ação, ocorrendo a reflexão sobre os resultados. Em seguida, na discussão de solução, apresentam-se os resultados para o grupo, havendo questionamentos. Caso alcance o consenso na proposição final, o grupo gera um documento, procedimento ou nova prática e define a forma de apresentação da solução para a empresa. Em caso negativo, discutem-se novamente as proposições. Concluindo essa etapa, realiza-se uma avaliação do ciclo. Na fase de consolidação, apresenta-se o resultado e discute-se com a empresa a proposição final para a solução do problema. Em seguida, define-se uma nova situação problemática e, com isso, inicia-se um novo ciclo. A Figura 1 apresenta a estrutura do modelo adaptado.

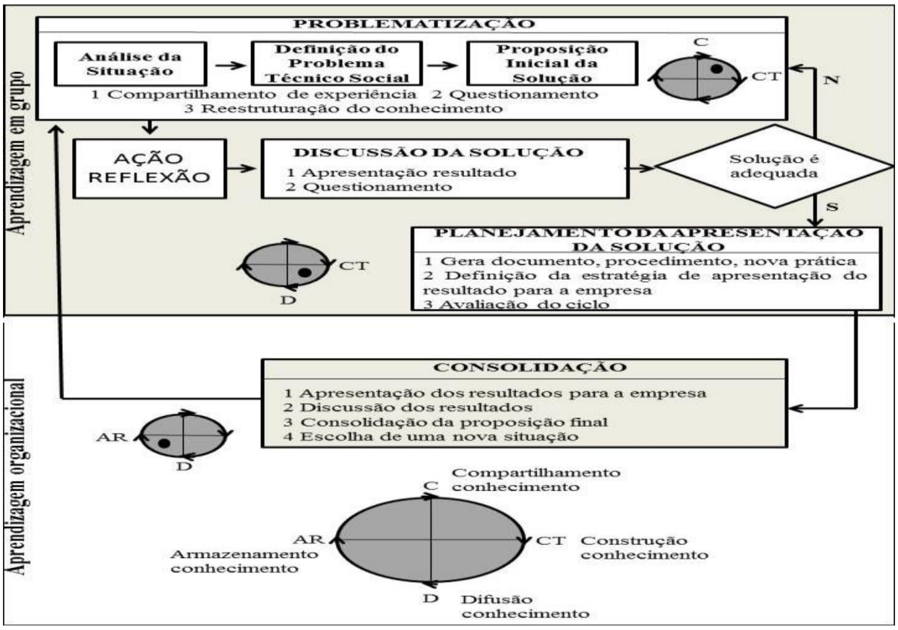

Figura 1: Modelo de capacitação. Fonte: NEVES (2006).

3 Método de pesquisa

Adotou-se a estratégia de pesquisa-ação, pois ela se desenvolveu com o interesse de mudança e participação de todos os envolvidos no processo. Thiollent (2007) diz que, para que uma pesquisa seja qualificada como pesquisa-ação, é vital a implantação de uma ação por parte das pessoas ou grupos implicados no problema sob observação. Além disso, é necessário que a ação seja não trivial, o que quer dizer uma ação problemática que mereça investigação, sob o ponto de vista científico, para ser elaborada e conduzida. Na pesquisa-ação os pesquisadores desempenham um papel ativo no equacionamento dos problemas encontrados, no acompanhamento e na avaliação das ações desencadeadas em função dos problemas.

O processo de pesquisa foi concebido de modo participativo, envolvendo o pesquisador e os dez engenheiros residentes (engenheiros de obra) participantes da pesquisa. Diante de uma situação problemática, os engenheiros envolvidos desenvolviam uma ação, que gerava uma reflexão e um planejamento de novas ações para o próximo ciclo. O pesquisador assumiu o papel de facilitador, o qual proporcionava orientações sobre material didático visando à reestruturação das bases teóricas e a busca pelo conhecimento por iniciativa própria dos engenheiros de obra participantes da pesquisa. Foi responsável também por organizar a dinâmica e os assuntos tratados nas reuniões. Além disso, no decorrer das reuniões, tomou uma postura indagativa perguntando a todo o momento aos gerentes de obra o porquê de ocorrerem os problemas listados em cada ciclo.

De acordo com Silva e Menezes (2005), a pesquisa do ponto de vista da forma da abordagem do problema é considerada qualitativa, pois considera que pode ser qualificável, o que significa traduzir opiniões e informações para classificá-las e analisá-las, através do uso de recursos e técnicas. Do ponto de vista de seus objetivos, a pesquisa é descritiva, pois visa descrever as características de um fenômeno e envolve o uso de técnicas e coletas de dados com observação sistêmica. Do ponto de vista dos procedimentos técnicos, ela é classificada como pesquisa-ação, pois foi elaborada com a participação e o comprometimento de mudança por parte de todos os envolvidos no estudo.

A pesquisa empírica desenvolveu-se investigando a implantação da ABP como o auxílio no desenvolvimento das competências demandadas pela empresa participante da pesquisa. Pode-se afirmar que cada ciclo correspondeu a uma fase de aprendizagem do pesquisador, tendo como ponto de partida a questão de pesquisa. De acordo com os resultados, o pesquisador realizou uma reflexão sobre aprendizagem individual e as competências necessárias aos engenheiros gestores de obra. Tais reflexões foram realizadas, entre um ciclo e outro, com a análise das transcrições das reuniões, em que se analisavam a frequência dos membros do grupo, o crescimento de participação nas reuniões (exposição de opiniões), o comprometimento com as atividades a serem desenvolvidas definidas pelo grupo e a percepção dos participantes com relação aos objetivos da organização. O estudo foi realizado de acordo com as etapas apresentadas na Figura 2.

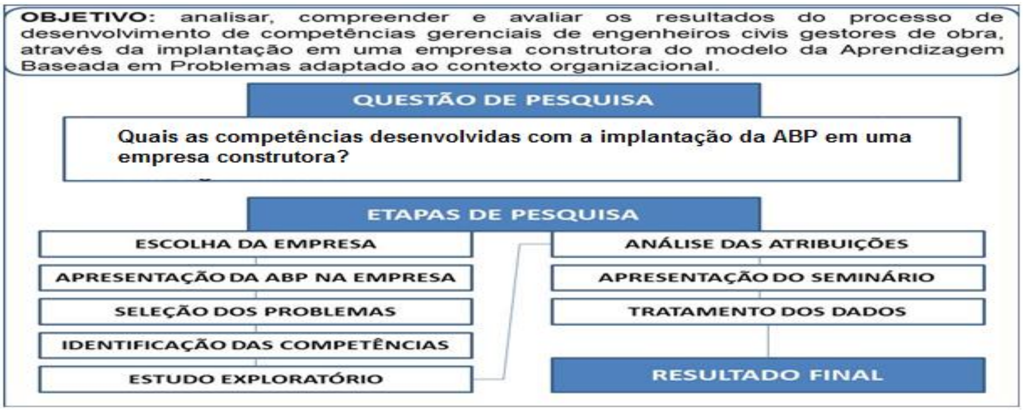

Figura 2: Delineamento da pesquisa.

Após o período de implantação da ABP na empresa, iniciou-se o tratamento dos dados. Tal análise buscou fundamentar-se nas observações do pesquisador no decorrer das reuniões, levando em consideração aspectos de aprendizagem e gestão organizacional de acordo com os relatos dos engenheiros residentes participantes do grupo.

O processo de análise dos dados iniciou-se com a leitura das transcrições das reuniões. Utilizaram-se trechos das reuniões, as entrevistas realizadas e documentos da empresa como organograma, procedimentos e alguns indicadores, objetivando cruzar as evidências existentes. A história do grupo no decorrer das reuniões foi contada de forma sequencial e cronológica, apresentando os fatos ocorridos julgados importantes para o pesquisador, objetivando analisar o processo de aprendizagem organizacional, o desenvolvimento de competência gerencial e aspectos da gestão organizacional da empresa.

Para facilitar a análise foram definidos os seguintes construtos: análise do contexto organizacional; análise da aprendizagem individual; análise da aprendizagem coletiva; análise da aprendizagem organizacional; e análise do sistema de gestão da empresa. As definições dos construtos foram baseadas na revisão bibliográfica, as fontes de evidências foram as transcrições das reuniões, as entrevistas realizadas com os diretores, subordinados e os engenheiros residentes (gerentes de obra), a observação direta in loco, as anotações pessoais do pesquisador e a análise de documentos internos da empresa serviram para enriquecer o processo de análise. As evidências foram elaboradas durante o processo de transcrição das reuniões e leitura delas, objetivando identificar expressões e palavras empregadas pelos engenheiros residentes em suas falas durante as reuniões. Essa identificação foi importante, pois guiou o pesquisador na análise das entrevistas.

4 Análise dos resultados

Inicialmente, foram analisados os problemas listados para cada tema, que representavam a prioridade a ser trabalhada de acordo com o interesse da empresa. Percebeu-se que grande parte dos problemas listados em todos os temas estava diretamente relacionada ao planejamento e controle de obras.

Para a identificação das competências gerenciais foram consideradas características pessoais e habilidades específicas do trabalho, além de algumas informações adicionais coletadas nas entrevistas realizadas entre os engenheiros e seus subordinados. A Figura 3 apresenta a média dos resultados dos engenheiros gestores de obra da empresa. Percebe-se que os gerentes (EU) tiveram uma visão de suas próprias competências que difere da opinião de sua equipe administrativa (OUTROS), que foram mais críticos sobre as competências dos engenheiros de obra (Quadro 1).

Observa-se que as maiores divergências de resultados estão nos itens liderança de grupo, trabalho em equipe, tomada de decisão e análise crítica, logo tais competências necessitam de maior atenção em seu processo de desenvolvimento. No decorrer do estudo exploratório através da percepção do pesquisador in loco nas reuniões, foi identificado que os engenheiros apresentam uma grande capacidade técnica, porém as dificuldades no gerenciamento de pessoas foram evidentes.

Durante o desenvolvimento dos ciclos, as dificuldades de implantação da ABP na empresa foram evidentes. O grupo não conseguiu quebrar a resistência em assumir as responsabilidades sobre os problemas apresentados, o que comprometeu a tomada de ação do grupo no processo de aprendizagem e, consequentemente, no desenvolvimento de competências gerenciais.

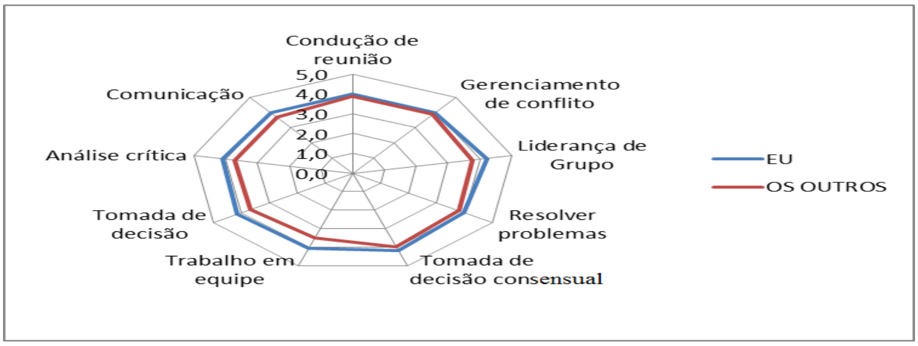

Figura 3: Média das avaliações de competências gerenciais.

Quadro 1: Resumo das avaliações

Tópicos abordados	Eu	Os outros
Condução de reunião	4,0	3,9
Gerenciamento de conflito	4,0	3,9
Liderança de grupo	4,2	3,8
Resolver problemas	4,0	3,8
Tomada de decisão consensual	4,2	4,0
Trabalho em equipe	4,0	3,5
Tomada de decisão	4,1	3,7
Análise crítica	4,1	3,7
Comunicação	4,0	3,7

O tema projetos foi trabalhado após a reestruturação das prioridades e esclarecimentos das metas e objetivo da implantação do programa da ABP na empresa. Foram realizadas três reuniões semanais, onde primeiramente se abordou os problemas existentes atualmente nas obras e quais as suas possíveis soluções. Abaixo apresenta-se a discussão dos assuntos abordados nas reuniões com os engenheiros residentes.

A reunião 1 contou com a participação de 7 engenheiros residentes. Iniciou-se com o coordenador do grupo perguntando sobre o por que do grupo ter redefinido a prioridade dos temas a serem trabalhados.

> Não estávamos conseguindo enxergar um norte no que vinha sendo trabalhado, não tínhamos uma meta e um objetivo claro, então decidimos redefinir a prioridade dos temas a serem discutidos. (Engenheiro residente 3).

A reunião se desenvolveu com a leitura dos problemas listados e com a discussão de suas possíveis soluções. Os engenheiros residentes discutiram sobre a criação de um setor específico de projetos na empresa e consequentemente a criação da figura do coordenador de projetos para solucionar ou minimizar os problemas apresentados.

> Os projetos chegam com atrasos e muitas vezes não definidos, precisamos de um setor específico de projetos (Engenheiro residente 6).

Os nossos projetistas são todos de fora né, então não temos um retorno rápido no caso de uma compatibilização, precisamos sim de um setor que além de nos ajudar nessa parte, possa também realizar um sistema de avaliação de fornecedores, no caso aqui de projetos (Engenheiro residente 1).

O coordenador do grupo perguntou aos engenheiros residentes o que cabiam a eles com relação a projetos, quem eram os responsáveis pela compatibilização de projetos.

[...] Nós podemos cobrar os projetos definidos né, ou pelo menos já terminados no tempo hábil [...] (Engenheiro Residente 1).

Na minha obra eu procuro compatibilizar os projetos com minha equipe de obra, encarregados e o mestre de obra. (Engenheiro residente 4).

Cobrar os projetos definidos ou pelo menos terminados em tempo hábil e com a criação do sistema de avaliação poder passar pra gerência as características e condições dos projetos encaminhados a obra. (Engenheiro residente 1).

Nesse momento foi retomada a discussão da criação do setor específico de projetos, onde, alguns engenheiros residentes defendiam a criação e outros relembravam que isso não era assunto correspondente as atribuições deles na empresa, falando que isso estava em um nível mais estratégico de alta direção. A discussão passou então para a criação de um sistema de avaliação de fornecedores, onde, decidiu-se elaborar um procedimento para atender as necessidades visando solucionar os problemas de projetos citados pelo grupo.

[...] temos que pensar em uma solução, vê qual o procedimento que vamos adotar pra solucionar nossos problemas, que tem problemas agente sabe, então vamos pensar como revolver isso. (Engenheiro Residente 1).

O coordenador do grupo perguntou o que mais incomodava os engenheiros com relação a projetos, o que é preciso ter para que esses problemas listados não ocorram.

[...] acredito que criando um setor específico de projetos, criando a figura do coordenador específico de projetos e criar um sistema de avaliação de fornecedores já resolveria grande parte dos problemas [...] (Engenheiro Residente 6).

O facilitador relembrou que o procedimento a ser criado, teria que ser aplicado na empresa, para que através dos resultados da ação (aplicação) o procedimento fosse validado ou não. A reunião encerrou com o coordenador do grupo lembrando que o procedimento deveria ser objetivo e que o mesmo abordasse ferramentas que pudessem ser aplicadas pelos próprios engenheiros em suas obras. Ficou definido que seria elaborado em conjunto o procedimento na próxima reunião, de acordo com o modelo que seria enviado pelo facilitador durante a semana.

A reunião 2 contou com a participação de 6 engenheiros residentes e objetivava ajustar de acordo com os interesses da organização o modelo de procedimento que tinha sido enviado pelo facilitador durante a semana. Iniciou-se a elaboração do procedimento em conjunto com os participantes expondo suas opiniões sobre cada item do procedimento como objetivo, documentos de referência, responsabilidades e ferramentas.

[...] só pra relembrar tá, hoje vamos tentar adequar esse procedimento de acordo com aquelas 3 situações que discutimos na reunião passada. (Facilitador).

[...] Que é a figura do coordenador de projetos, a criação do setor de projetos e a função do engenheiro de obra com relação a projetos. (Coordenador).

O grupo seguiu a elaboração do procedimento sempre expondo suas opiniões e entendimentos a respeito de cada tema abordado, o facilitador a todo o momento lembrava o grupo que a ideia era atender as necessidades de obra dos engenheiros para solucionar os problemas referentes a projetos. O coordenador relembrou aos engenheiros residentes que sua função era receber na obra os projetos com um mínimo de informação necessária para iniciar a obra, além disso, era necessário que a figura do coordenador de projetos fosse justificada dentro do procedimento que vinha sendo criado.

Na etapa de definição das responsabilidades dos envolvidos no projeto, ficou claro que na empresa não havia uma definição das atribuições de seus engenheiros residentes, pois, os participantes do grupo encontraram dificuldades em citar suas responsabilidades com relação a questões de projetos. A reunião seguiu com os ajustes no procedimento visando justificar a criação da figura do coordenador e o setor específico para projetos. Encerrou-se a reunião faltando apenas os ajustes nas ferramentas em anexo ao procedimento, que ficou para próxima reunião.

A reunião 3 contou com a participação de apenas 50% do engenheiros participantes do grupo e objetivava finalizar o procedimento incluindo as ferramentas em anexo que iriam atender as necessidades que tinham sido definida pelo grupo. A reunião iniciou-se com o facilitador pedindo para que cada membro do grupo listasse de acordo com o entendimento deles quais seriam as suas atribuições dentro do canteiro de obra.

A reunião se desenvolveu com as discussões das melhores práticas e ferramentas a serem inclusas no procedimento.

> Eu busquei informações em procedimentos com relação a coordenação e controle de projetos (Engenheiros residente 6).
>
> Tenho algumas ferramentas aqui que podem ser úteis (Engenheiro residente 5).

Ao final da reunião estavam definidas as ferramentas que seriam incorporadas ao procedimento, acordou-se então que o facilitador iria formatar e finalizar o procedimento incluindo as ferramentas escolhidas em conjunto e enviaria ao grupo para que fosse validade por todos. O fechamento do ciclo de projetos se consolidou com a apresentação do procedimento para a alta direção da empresa, onde, participaram dois gerentes de obra, um gerente de planejamento e a gerente do setor de Recursos humanos, tal apresentação foi conduzida por um engenheiro residente que representou o grupo.

Neste ciclo o grupo demonstrou objetividade no tratamento das informações, procurou de forma clara e na troca de experiência adequar um procedimento de projetos, visando atender as suas necessidades de obra, porém, evidente a resistência por parte dos participantes do grupo em assumir suas responsabilidades sobre os problemas, os mesmos, justificavam os problemas com inúmeros fatores externos a obra, o que comprometeu a tomada de ação do ciclo. Com relação à participação nas reuniões, foi notório o progresso do grupo, pois, alguns engenheiros passaram e expor o seu entendimento e sua experiência sobre o assunto. Um ponto que chamou a atenção do pesquisador foi o fato da empresa não possuir de forma bem definida e clara as atribuições dos engenheiros de obra da empresa, fato confirmado pelo resultado da entrevista com todos os engenheiros de obra e dois gerentes de obra (representantes da alta direção).

A análise do resultado da entrevista mostrou uma divergência de entendimento entre os engenheiros residentes e a alta direção, ou seja, a empresa não possui de forma clara quais são as atribuições dos seus engenheiros de obra ou não consegue passar tal informação para que os mesmo absorvam e saibam quais suas obrigações a serem desempenhadas. Foram citados pelos engenheiros vinte quatro atribuições dentro do canteiro de obras, entre as quais se destacam pela maior repetição as: coordenação da equipe administrativa da obra, acompanhamento e controle do orçamento da obra e verificar itens de segurança do trabalho. Do ponto de vista dos gerentes representantes da alta direção foram citados vinte e uma atribuições dentro do canteiro de obra, dentre as quais se destacam pela maior repetição: acompanhamento dos serviços da obra, controlar todos os projetos de obra e verificar sua conformidade e liderar a equipe administrativa da obra.

Analisando os aspectos do contexto organizacional, destaca-se neste ciclo o comprometimento da alta direção com a implantação do programa, pois, quando convidados para participar do seminário de apresentação do procedimento que tinha sido elaborado, todos compareceram na reunião. Do ponto de vista da aceitação e entendimento do programa pelos membros do grupo notou-se desenvolvimento, pois, em há trechos em que os engenheiros residentes cobram metas e objetividade para o procedimento que vinha sendo elaborado.

Nos aspectos de aprendizagem individual com relação à competência de resolução de problemas foi notório o progresso dos engenheiros neste sentindo, pois, os membros trouxeram informações e ferramentas objetivando a resolução dos problemas de projetos existentes nas obras. A competência de comunicação se manteve como no ciclo anterior, com os membros do grupo se expressando de forma clara, porém, alguns se mostraram reativos a ideias expostas por outros membros. Análise de condução de reuniões foi prejudicada devido os membros do grupo não assumirem o papel de coordenador do grupo, porém, pode ser identificado a dificuldade da maioria do grupo em cumprir o horário definido para início da reunião. A mudança de comportamento foi observada neste ciclo, pois, foram esclarecidos os objetivos, o que proporcionou uma maior participação por parte dos engenheiros residentes nas reuniões, percebeu-se membros que não se pronunciavam e começaram a expor suas ideias durante as reuniões. A capacidade de análise crítica do grupo neste ciclo foi desenvolvida, pois, o grupo criou o procedimento procurando indagar, entender e analisar melhor o processo relacionado a projeto.

A aprendizagem coletiva foi estimulada neste ciclo com a criação do procedimento de projeto, o grupo procurou trocar experiência, informações e técnicas para a elaboração do mesmo, visando à melhoria nos procedimentos e estimulando mudanças de regra no modo de agir dos engenheiros. O grupo teve dificuldade para trabalhar em equipe na elaboração do procedimento, muitas ideias foram apresentadas o que provocou longas discussões para definição e continuidade da elaboração do procedimento. O grupo procurou valorizar as opiniões de todos que participavam, concordando em sua maioria com o que era definido e decido pelo grupo. No começo da elaboração do procedimento dois engenheiros estavam com conflitos de ideias a respeito das obrigações dos mesmos com relação ao tema projetos, fato que estimulou e desenvolveu o gerenciamento de conflito do grupo. Com relação à liderança de grupo foi notado que os mesmos dois engenheiros do ciclo anterior tinham uma postura mais ativa com relação aos outros, ou seja, não houve um terceiro destaque neste sentindo, não havendo desenvolvimento de tal competência.

A aprendizagem organizacional ocorreu com a disseminação das informações trabalhadas no ciclo aos demais setores da empresa, através do seminário para apresentação do procedimento elaborado, onde, participaram representantes da alta direção da empresa como: gerente de planejamento, gerente de Rh e dois gerentes de obra, o seminário foi apresentado por um engenheiro residente que representou o grupo.

5 Conclusões

Observou-se que as competências técnicas passaram a assumir na prática uma posição secundária em relação às funções de gestão da obra, que vão desde o controle financeiro do suprimento de materiais, passando pela mobilização e desmobilização da mão de obra e pelo acompanhamento da liberação de recursos com o agente financeiro, reforçando o papel do engenheiro gestor de obras de não planejador, centralizando o controle e a busca de resultados no curto prazo.

Analisando os resultados da pesquisa e os aspectos organizacionais da empresa, foi identificado que as atividades gerenciais estão sendo impactadas, pois os gerentes devem se preocupar com o processo da solução dos problemas, e não com o resultado. Necessitam ver o problema como fazendo parte da solução. Observa-se que a ABP potencializou as competências referentes ao trabalho em equipe, liderança de grupo, comunicação, resolução de problemas, gerenciamento de conflitos, disseminação da informação e pensamento sistêmico.

A empresa precisa criar um ambiente propício à troca de informações entre seus setores, objetivando o engajamento das pessoas envolvidas em seu processo. É necessário certificar-se de que as pessoas sabem o propósito de seu trabalho e como ele contribui para que a organização alcance seus objetivos. Reconhecer e apreciar o trabalho desenvolvido pelos colaboradores também é válido. Vale ressaltar que feedbacks claros proporcionam o desenvolvimento de um bom trabalho, mas para isso as pessoas precisam de informações claras e em tempo hábil. É necessário não apenas avaliar o comportamento ou os resultados, mas também fazer com que as pessoas percebam sua importância para o sucesso da organização.

Em relação ao modelo, é importante ressaltar que o problema trabalhado deve estar alinhado aos objetivos da organização e aos interesses do grupo (coletivo); de preferência real e que esteja ocorrendo no momento (vinculado ao dia a dia); relacionado com os processos gerenciais; relevante para a prática profissional. Ainda, a decisão do curso de ações a serem tomadas para sua resolução e implementação deve ser de responsabilidade do gerente de produção; e levar em consideração os aspectos humanos, sociais e técnicos. Isso faz com que o problema estimule a aprendizagem tanto individual quanto grupal e organizacional. É preciso que os membros do grupo entendam a necessidade das mudanças e das melhorias.

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Virtual Reality as a Learning Tool in the Formation of Academic Construction

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Abstract

This article presents the results of a case study of civil engineering students at the Federal University of Pará, Brazil, using the Virtual Building (ALVI), a virtual learning environment developed under the concepts of desktop virtual reality, which is made use of personal computers commonly used in the computer labs of higher education institutions. The system teaches executive masonry process, from cleaning the area where it will run until it locks in place with the roof structure by wedging. The results show the efficiency of the use of virtual reality as a teaching tool having as parameter that over 70% of students who used the tool were able to memorize the masonry execution sequence as well as important concepts related to the topic, with only one application session. It also shows high levels of motivation and acceptance tool.

Keywords: Virtual Reality, Learning, Interactivity, Masonry.

A Realidade Virtual como ferramenta de aprendizagem na formação do acadêmico da construção civil

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Resumo

Este artigo apresenta os resultados de um estudo de caso, realizado com estudantes de engenharia civil da Universidade Federal do Pará, Brasil, utilizando o Alvenaria Virtual (ALVI), um ambiente virtual de aprendizagem desenvolvido segundo os conceitos de realidade virtual desktop, a qual se faz uso de computadores pessoais comumente utilizados nos laboratórios de informática das instituições de ensino superior. O sistema ensina o processo executivo da alvenaria, desde a limpeza da área onde será executada até o seu travamento com a estrutura do telhado, através do encunhamento. Os resultados mostram a eficiência do uso da realidade virtual como ferramenta didática, tendo como parâmetro que mais de 70% dos alunos que utilizaram a ferramenta conseguiram memorizar a sequência de execução da alvenaria, assim como conceitos importantes relacionados ao tema, com apenas uma sessão de aplicação. Mostra ainda índices elevados de motivação e aceitação da ferramenta.

Palavras chaves: Realidade Virtual, Aprendizagem, Interatividade, Alvenaria.

1 Introdução

A globalização vivenciada no cenário mundial, a partir do final do século passado, trouxe mudanças significativas no cotidiano do homem moderno na busca pela excelência. A introdução consciente de conceitos e ferramentas de computação é exigida pelas mudanças que estão ocorrendo no mundo profissional. Na construção civil, o uso da computação aplicada tornou-se uma ferramenta essencial no desenvolvimento e acompanhamento de projetos.

Whyte (2002) diz que a realidade virtual está influenciando a maneira como os espaços são projetados e mudando a nossa experiência com o ambiente construído. Primeiramente descrita como mais útil aos arquitetos, por permitir caminhar junto com o cliente em torno de um novo edifício antes mesmo que seja construído, a realidade virtual vem sendo usada dentro da equipe de projetos e da cadeia de suprimentos para visualizar e gerenciar dados de engenharia e projeto cada vez mais complexos.

A realidade virtual pode ser descrita como um conjunto de tecnologias, que apoiadas no uso de computadores, simulam a realidade existente ou a realidade projetada. Esta ferramenta permite aos utilizadores do computador a participação em ambientes tridimensionais, possibilitando-lhes que interajam com objetos virtuais. Diante desta realidade, é que se vislumbra a criação de ambientes virtuais de aprendizagem que funcionem como laboratórios, os quais possam simular situações reais do cotidiano da construção civil que possibilitará o aperfeiçoamento técnico destes profissionais e/ou os auxiliará em tomadas de decisões, assim como ferramenta de aprendizado para acadêmicos da área.

Hoje, através da realidade virtual, vislumbra-se a computação não apenas como instrumento no desenvolvimento e acompanhamento de projetos, mas como parte integrante do processo de aprendizado e treinamento dentro do contexto da construção civil, ela prende a atenção do aprendiz e permite uma participação mais ativa na busca pelo conhecimento.

Pautado no uso de novas tecnologias na educação o artigo objetiva apresentar os resultados da aplicação de um ambiente virtual de aprendizagem, desenvolvido segundo os conceitos de realidade virtual, com acadêmicos da construçao civil.

2 Metodologias Ativas e Novas Tecnologias na Educação

Diante da globalização do mercado e cientes desta realidade, as instituições de ensino superior vêm buscando novas metodologias de ensino que rompam a tradicional aula expositiva ministrada pelos professores e tornem os alunos mais participativos na busca pela formação profissional.

Sesoko e Mattasoglio Neto (2014) relatam que, nas últimas décadas, as escolas de engenharia estão buscando novas metodologias que supram as necessidades exigidas para um bom engenheiro, que são os conhecimentos específicos e as habilidades transversais (capacidade de se expressar, pró-atividade, liderança, trabalho em equipe e gestão de projetos), e vêm estudando as metodologias ativas, que, segundo os autores, são aquelas cujo aprendizado está centrado no aluno, onde ele assume a corresponsabilidade pelo aprendizado, passando a exercer um papel ativo. Portanto, o professor passa a ser um tutor, com papel de facilitador, e tem, como função, estimular, motivar, provocar e questionar os estudantes, deixando de ser o único detentor e transmissor do conhecimento.

Neste contexto, o componente tecnológico tem papel relevante. As tecnologias da informação e comunicação (TIC's) estão transformando o mundo e é importante considerá-las na área da Educação. Segundo Rocha e Joye (2013), a filosofia do uso das TICs consiste em inserir o aluno em situação de participação mais ativa na sua aprendizagem.

Wildauer (2013) diz que as novas tecnologias de ensino poderão disponibilizar novos ambientes com novas características, entre os quais, estão os treinamentos via realidade virtual. Para Pantelidis (2009), a realidade virtual motiva os alunos, pois requer interação e incentiva a participação ativa à passividade.

Apresenta-se, então, ao aprendiz, uma nova tecnologia de aprendizagem que lhe permite uma participação mais ativa no processo de busca pelo conhecimento.

3 Realidade Virtual

Segundo Kirner e Kirner (2011), a "Realidade Virtual (RV) é uma interface computacional que permite ao usuário interagir em tempo real, em um espaço tridimensional, gerado por computador, usando seus sentidos, através de dispositivos especiais".

A RV pode ser caracterizada pela coexistência integrada de três ideias básicas: (i) imersão, (ii) interação e (iii) envolvimento. Desta forma, Lamounier Jr. (2006) descreve essas ideias básicas, ou princípios, da RV da seguinte forma: (i) A imersão está ligada ao sentindo de se estar dentro do ambiente. Para tanto, o uso de dispositivos específicos são requeridos; (ii) A interação está associada com a capacidade de o computador detectar as entradas do usuário e modificar instantaneamente o ambiente virtual. Estas modificações instantâneas são provocadas, em alguns casos, para providenciar ao usuário a sensação de navegar (explorar) pelo ambiente virtual; (iii) O envolvimento está ligado ao grau de motivação para o engajamento de uma pessoa com determinada atividade, podendo ser passivo (visualização do ambiente virtual) ou ativo (participação no ambiente virtual).

Para Botega e Cruvinel (2009), os sistemas de RV diferem entre si de acordo com os níveis de imersão e de interatividade proporcionados ao usuário. A RV pode ser classificada, em função do senso de presença do usuário, em imersiva ou não imersiva (TORI e KIRNER, 2006).

Kirner e Kirner (2011) relatam que a RV implementada no modo janela (monitor ou projeção, por exemplo) é denominada não imersiva, enquanto que a implementação baseada em capacete (HMD) ou salas de multiprojeção e em outros dispositivos multisensoriais é denominada imersiva.

O Laboratório de Realidade Virtual (LaRV) da Faculdade de Engenharia da Computação da Universidade Federal do Pará (UFPa) denomina a categoria de aplicações de RV que utiliza computadores domésticos de médio porte de RV *Desktop*, sendo na atualidade sua principal área de atuação.

3.1 Sistema de Autoria de Instruções Técnicas Virtuais

É um aplicativo computacional desenvolvido segundo os conceitos de RV *Desktop*, fruto da parceria entre o LaRV e a Eletronorte S.A, originalmente criado para desenvolver Instruções Técnicas Virtuais (ITV's) de operação e manutenção de uma usina hidrelétrica, com a finalidade de treinamento e capacitação.

As instruções técnicas são roteiros bem definidos com desenhos 2D e atividades em formato textual. A ideia principal das ITV's é transformar essa descrição textual dos procedimentos em uma demonstração visual e interativa do processo, tornando mais simples e atraente o aprendizado.

Ribeiro *et. al.* (2010) relatam que a construção de uma ITV é feita visualmente através de uma sequência de passos e cada passo representa uma etapa no procedimento descrito pela instrução técnica. A animação completa da ITV é composta de um ou mais passos. Estes passos são criados pelo usuário e possuem uma duração de tempo definida por este, de modo que ao término do tempo definido para um passo, o próximo passo é carregado e pode então ser animado. Um passo é composto por um cenário inicial e por animações que irão modificar este cenário (RIBEIRO *et. al.* 2009).

A transição entre os passos pode ser realizada de três formas: (a) normal: o próximo passo é carregado automaticamente de modo que não se percebe a passagem de um passo a outro; (b) fade: ao fim de um passo, ocorre o escurecimento da cena e, no início do próximo passo, ocorre o clareamento da cena; (c) mesh ou condicional: ao fim de um passo, a ITV espera por uma interação do usuário (através do clique do mouse) com objetos do mundo virtual, de modo que, se o objeto correto for acionado, o próximo passo será carregado. Pode-se escolher um ou mais objetos da cena para serem os acionadores da transição (RIBEIRO *et. al.* 2009).

4 Alvenaria Virtual (ALVI)

O ALVI é um ambiente de aprendizagem em RV desenvolvido sobre a plataforma do Sistema de Autoria de ITV's, fruto da parceria entre o Programa de Pós-Graduação em Engenharia Civil (PPGEC) da UFPA e o LaRV. É pautado nos conceitos de instruções técnicas, passos e transição do Sistema de Autoria que nasce o ALVI, com a finalidade de apresentar o passo a passo para a execução de uma parede de alvenaria de vedação. A Figura 01 mostra a estrutura de desenvolvimento do ALVI.

Figura 1: Estrutura de desenvolvimento do ALVI.

O cenário do ALVI consta de um canteiro de obras com uma edificação já iniciada, faltando a execução de uma parede e um barracão onde são guardadas as ferramentas, equipamentos e matérias relacionadas com a execução da alvenaria.

Os objetos que compõem o cenário e as ferramentas utilizadas para a execução da alvenaria foram produzidos em softwares de modelagem 3D, posteriormente texturizados com imagens do objeto real, fato que garantiu um maior realismo a esses objetos. Para finalizar o processo de construção desses objetos, eles foram exportados a partir do 3D Studio Max no formato MESH, padrão aceito pelo Sistema de Autoria, através do *plugin* oFusion e, finalmente, posicionados no ambiente 3D do aplicativo.

Após os objetos estarem devidamente posicionados, eles passaram por transformações do tipo translação, rotação, escalamento, transparência, contorno, entre outras, e deram origem a cada um dos passos que compõem o processo executivo da alvenaria.

A Figura 02 mostra algumas imagens de passos que são realizadas pelo ALVI durante o processo de execução da alvenaria: (a) a preparação da estrutura de concreto para receber a alvenaria através do chapisco; (b) o processo de levantamento da alvenaria, destacando a descontinuidade da junta vertical através do inicio da segunda fiada com meio tijolo e a repetição das fiadas impares e das fiadas pares; (c) a realização do travamento da alvenaria com a viga através do encunhamento.

Figura 2: Passos realizados pelo ALVI para a execução da alvenaria.

O ALVI permite três modos diferentes de visualização para fins de aprendizagem e treinamento, que são: (a) automático: assim que acionado, uma animação com a sequência de execução da alvenaria começa a rodar de forma instantânea; (b) guiado: neste modo, é necessário a interação do usuário com o ambiente através do acionamento, com o mouse, de algum objeto devidamente sinalizado e comentado através de áudio de narração e/ou caixa de texto; (c) livre: neste modo, a interação do usuário ocorre de forma que não haja nenhuma informação por parte do sistema, sendo necessário que o usuário conheça todos os procedimentos de execução.

5 Estudo de Caso

Objetivando avaliar o ALVI como ferramenta didática, foi realizado um estudo de caso durante dois encontros, com duração de aproximadamente uma hora cada, o primeiro com 12 alunos usuários; o segundo, com 18, perfazendo-se um total de 30 alunos usuários, todos do primeiro módulo do curso de engenharia civil da Universidade Federal do Pará, Brasil, de modo que as amostras possuíssem nenhum ou pouco conhecimento sobre o tema "Sistema Construtivo de Alvenaria". A Figura 03 mostra dois momentos de aplicação do ALVI com os alunos durante a realização do estudo de caso.

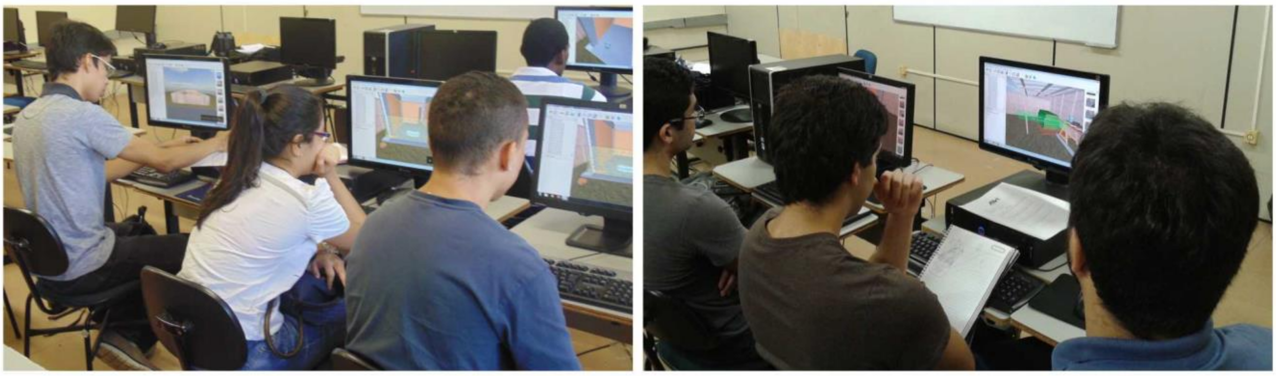

Figura 3: Aplicação do ALVI durante o estudo de caso.

Os encontros se desenvolveram em três etapas. Na primeira etapa, foi aplicado um questionário (Pré-Teste) com o objetivo de detectar se os alunos usuários possuíam conhecimento prévio a respeito do tema "Processo Construtivo de Alvenaria", assim como de conceitos e/ou definições sobre tópicos relevantes relacionados ao tema, tais como: junta de amarração, escantilhão, encunhamento, verga, contraverga e ferro cabelo. A segunda etapa constou da utilização do ALVI por parte dos alunos através, primeiramente, do modo automático de visualização e, posteriormente, do modo guiado. Na terceira e última etapa, os alunos usuários responderam a dois questionários: um (Pós-Teste) com o objetivo de detectar os conhecimentos adquiridos sobre os tópicos mencionados na primeira etapa, assim como acertar a sequência correta do processo construtivo de alvenaria; o outro, objetivando avaliar o ALVI como ferramenta didática de aprendizagem.

5.1 Avaliação

A avaliação do ALVI como ferramenta didática foi realizada segundo o modelo desenvolvido por Savi (2011) em sua tese, que teve, como objetivo principal, realizar avaliações da qualidade dos jogos educacionais por meio da reação dos alunos a respeito dos subcomponentes de: (i) motivação: o jogo consegue motivar os alunos a utilizarem o recurso como material de aprendizagem?; (ii) experiência do usuário: avaliação da experiência de utilização do jogo. Por exemplo: o jogo é divertido?; (iii) aprendizagem: se o jogo gera uma percepção de utilidade educacional focados na aprendizagem de curto e longo prazo.

Cada um dos três subcomponentes é composto por algumas dimensões: o subcomponente motivação é composto por quatro dimensões (atenção, relevância, confiança e satisfação); o subcomponente experiência do usuário é composto por seis dimensões (imersão, desafio, competência, divertimento, controle e interação social); já o subcomponente aprendizagem é composto por cinco dimensões (conhecimento, compreensão, aplicação, aprendizagem de curto termo e aprendizagem de longo termo).

Desta forma, o modelo teórico para avaliação de jogos educacionais é composto pela reação do usuário, seus três subcomponentes e suas quinze dimensões. Considera-se que, neste modelo, há uma relação causal entre os subcomponentes e que a qualidade do jogo como material educacional será determinado pela reação do aluno ao efeito motivador do jogo, a experiência de jogar e ao ganho de aprendizagem percebido.

Segundo o autor, não basta que um jogo seja didaticamente adequado e promova a aprendizagem, ele também precisa ser capaz de motivar os alunos a estudarem e proporcionar uma boa experiência.

Vale ressaltar que o ALVI não está enquadrado como jogo, pois, em sua estrutura, não existe conquista de pontos nem competição com outros usuários, porém, foi relevante avalia-lo segundo o modelo desenvolvido por Savi (2011), pois ele aborda um grande número de itens de extrema importância para avaliação do desempenho didático do ALVI, entre os quais estão: a facilidade de uso como material de estudo, conteúdo relevante para a formação profissional, eficiência do ALVI como ferramenta de aprendizagem, entre outras, assim como faz a avaliação do envolvimento do aluno usuário com o ambiente virtual de aprendizagem do ALVI e sua motivação em utilizá-lo.

5.2 Resultados

O Gráfico 01 mostra que 70% dos alunos usuários que utilizaram o ALVI durante o estudo de caso afirmaram não conhecer o processo construtivo de alvenaria, condição ideal proposta para o Estudo de Caso.

Gráfico 01: Conhecimento prévio do processo construtivo de alvenaria.

O Gráfico 02 mostra a relação de conhecimento dos conceitos e/ou definições dos tópicos relevantes à alvenaria, anteriormente citados, antes e depois da utilização do ALVI no estudo de caso.

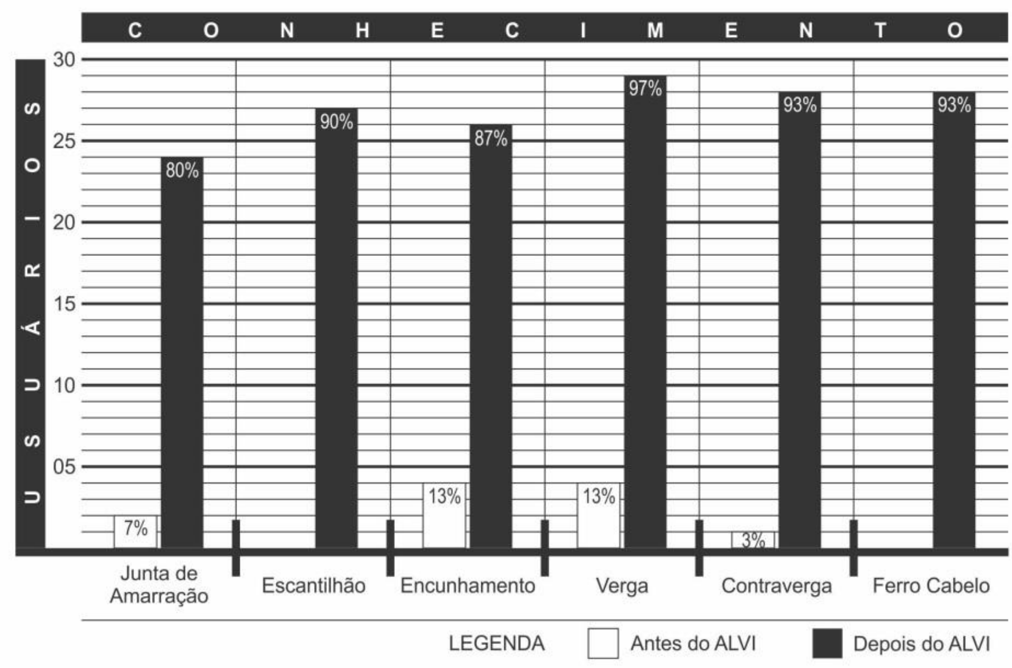

Gráfico 02: Relação de conhecimento dos conceitos e/ou definições antes e depois do uso do ALVI

Percebe-se com clareza que o conhecimento dos conceitos e/ou definições antes do uso do ALVI era pouco ou nenhum, como é o caso dos conceitos de Escantilhão e Ferro Cabelo, e, após o uso, houve significativa conquista de conhecimento, obtendo resultados superiores ou iguais a 80% em todos os conceitos e/ou definições.

A avaliação solicitou ainda que os alunos usuários do ALVI enumerassem a sequência lógica dos passos para a execução da alvenaria. O Gráfico 03 mostra que 70% dos entrevistados conseguiram êxito na enumeração e acertaram a sequência do processo construtivo de alvenaria após a utilização do ALVI.

Gráfico 03: Acertaram o processo construtivo após a utilização do ALVI

Avaliação do ALVI utilizando o questionário de avaliação de jogos educativos.

A avaliação do ALVI como ferramenta didática foi realizada através de um questionário estruturado com 27 itens baseados nos três subcomponentes: motivação (10 itens), experiência do usuário (14 itens) e aprendizagem (3 itens), como proposto por Savi (2011). Para definir as notas, foi atribuída uma escala que vai de -2 a +2.

Subcomponente Motivação

De modo geral, foi possível observar que o ALVI teve um efeito positivo na motivação dos alunos usuários. Houve uma concentração maior de notas +1 ou +2 em todos os itens, sendo importante ressaltar que, os itens "facilidade de entender o ALVI" e "o conteúdo é relevante" obtiveram as maiores percentagens de notas +2 no componente motivação, com 83,3% de indicação.

Subcomponente Experiência do Usuário

Este foi o componente que menos recebeu notas +1 ou +2, porém, vale ressaltar que dois itens receberam o percentual de 90% de notas +1 ou +2 atribuídas, que são: "os que gostariam de utilizar o ALVI novamente" e “os que o indicariam para seus colegas”, que, de modo geral, indica uma grande aceitação pela utilização do ALVI como ferramenta de aprendizagem.

Subcomponente Aprendizagem

Na percepção dos alunos usuários, o ALVI contribuiu de forma relevante para a aprendizagem. 83,4% dos alunos usuários atribuíram notas +1 ou +2 para o item “contribuiu na aprendizagem do tema ‘processo construtivo de alvenaria’”. 86,7% deram notas +1 ou +2 para o item que dizia que “o ALVI foi eficiente para a aprendizagem em comparação com outras atividades”. 90% de alunos usuários atribuíram notas +1 ou +2 e acham que a utilização do ALVI vai contribuir para o seu desempenho profissional

6 Conclusões

A inclusão de sistemas computadorizados com fins didáticos e de aprendizagem não é uma novidade nos meios acadêmicos, porém, muitos não passaram de uma simples informatização dos conteúdos programáticos e a utilização de um ou outro recurso multimídia.

A experiência, em primeira pessoa vivenciada pelo usuário de RV, permitida através da interação deste com o ambiente tridimensional simulado pelo computador, agrega a ele um fator motivador por torná-lo personagem ativo no processo de conquista por novos conhecimentos. Esses ambientes sintéticos com grande poder de simulação permitem que o usuário visualize situações que, na vida real, são difíceis de serem vivenciadas, seja pela dificuldade de acessos ou pela grande diferença de escalas.

Os resultados obtidos com a aplicação do ALVI vêm confirmar que as características da RV, entre elas estão a capacidade de simulação e a interatividade em tempo real, estimulam a aprendizagem, por permitirem um maior envolvimento do aluno usuário no contexto de aprendizado. Desta forma, o ALVI mostrou-se como uma ferramenta completamente viável para o processo de ensino aprendizagem.

Outro fator de grande relevância é a condição atemporal da RV, característica herdada pelo uso dos computadores na educação, que permite a cada usuário adequar ao seu ritmo o processo de aprendizagem, permitindo ainda que este processo se repita inúmeras vezes até o total entendimento da informação.

A RV *Desktop* baseada na utilização de computadores pessoais, comumente utilizados em laboratórios de informática de nossas instituições de ensino, pode transformá-los em ambientes de experimentos virtuais nas mais diversificadas áreas de conhecimento humano, com a vantagem de que esses experimentos poderão ser repetidos infinitas vezes sem que haja custos adicionais, possibilitando, ainda, uma economia de materiais e equipamentos reais, pois os aprendizes só realizarão os experimentos reais após o domínio de seus procedimentos no campo virtual.

A área de educação (aprendizagem) tem muito a ganhar com a RV tanto no ensino presencial quanto no ensino a distância. Porém, para uma perfeita utilização desta ferramenta com esta finalidade, deve-se olhá-la sobre um ponto de vista de uma abordagem didático pedagógica que possa valorizar seu conceito e princípios em seu sistema de ensino aprendizagem.

O uso da RV como ferramenta didática garante ao usuário autoria ou coautoria na busca pelo aprendizado, situação também desejada pelas metodologias ativas de ensino que clamam por uma participação mais ativa dos estudantes em sua formação profissional. O aluno torna-se protagonista no processo de construção do seu conhecimento.

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Methodology for technical drawing education using open source software and project based learning

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Abstract

The advancement of technology in all areas puts new challenges in education. We must meet a new generation, which is surrounded these advances and requiring the inclusion of new practices and innovative teaching methodologies. This promotes a reflection on the pedagogical practices used and their effectiveness in the process of teaching and learning. The technical drawing discipline, present in technical high school courses and higher education, is directly affected by this progress. This article is a methodology that aims to present a new approach for application in the technical drawing discipline, using open source software and project based learning, in order to update and adapt the discipline to current technological innovations.

Keywords: technical drawing; project based learning; open source software.

Proposta de uma estratégia de ensino-aprendizagem na disciplina de desenho técnico utilizando software livre e metodologia baseada em projetos

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Resumo

Com o avanço tecnológico em todas as áreas, novos desafios surgem na educação. É necessário atender uma nova geração, a qual é cercada destes avanços e requerendo a inserção de novas práticas e metodologias inovadoras de ensino. Isto promove uma reflexão sobre as práticas pedagógicas utilizadas e a efetividade das mesmas no processo de ensino e aprendizagem. A disciplina de desenho técnico, presente em cursos de ensino médio técnico e no ensino superior, é diretamente influenciada por este avanço que passa por uma transição do papel ao desenho assistido por computador e suas aplicações em projetos. Este trabalho tem como objetivo apresentar uma nova abordagem para aplicação na disciplina de Desenho Técnico, utilizando software livre e a metodologia baseada em projetos, com o intuito de atualizar e adequar a disciplina às inovações tecnológicas atuais.

Palavras chave: desenho técnico; abordagem baseada em projetos; software livre.

1 Introdução

Nos processos educacionais, os pesquisadores em métodos de ensino e aprendizagem concentram seus esforços em busca da evolução das técnicas de aprendizagem de forma a superar as dificuldades provenientes ao processo ensino e a acompanhar as evoluções tecnológicas. As facilidades de acesso a informação e ao uso de recursos computacionais, por sua vez, permitem que sejam desenvolvidos e aplicados métodos de ensino e aprendizagem que priorizam a pesquisa como atividade criadora de conhecimento.

A Aprendizagem Baseada em Projetos (ABP) é uma metodologia de ensino e aprendizagem inovadora. Incide sobre conceitos e princípios de uma disciplina, envolvendo os alunos em atividades de pesquisa para resolução de projetos e seus respectivos problemas relevantes, permitindo aos mesmos trabalhar de forma autônoma para construir seu próprio saber, baseada em projetos de situações reais. Metodologias baseadas em projetos permitem aos educadores conduzirem as aulas com uma maior proximidade aos alunos, à realidade atual e as necessidades de empresas, possibilitando a preparação mais completa do futuro profissional.

Dym & Little (2010) comentam que nesta abordagem de ensino, deve-se entender que a atuação do docente é de facilitador e orientador do processo de aprendizagem dos alunos, conduzindo o aluno à uma construção própria de conhecimentos. Se utilizarmos este conceito, integrado à facilidade de uso de hardware e software que temos atualmente, podemos preparar melhor o aluno para o enfrentamento de seus futuros desafios.

Com isto pretende-se integrar este projeto também ao software livre, entendido aqui como o software que respeita a liberdade e senso de comunidade dos usuários, que possuem a liberdade de executar, copiar, distribuir, estudar, mudar e melhorar o software. Com essa liberdade, os usuários - tanto individualmente quanto coletivamente – controlam o programa e o que ele faz por eles, servindo de perfeito apoio a ABP.

Este projeto apresenta a metodologia necessária para que se possa conduzir uma revisão conceitual, propor uma metodologia adequada, introduzir a abordagem em sala de aula e analisar os resultados que serão obtidos. Atualmente o mesmo encontra-se em fase de aplicação no Colégio Técnico de Lorena, da Universidade de São Paulo.

2 Fundamentação teórica

2.1 Metodologia baseada em projetos

Faz-se necessário atualmente emergir a necessidade de dotar os professores de conhecimentos e habilidades de natureza pedagógica (GIL, 2005). Para Freitas et al (2014), a complexidade do cenário educacional evidencia que o simples ensinar de conceitos e teorias já não é mais o bastante. Percebe-se que é importante e cada vez mais necessário capacitar os alunos para que possam gerenciar seu próprio conhecimento, adquirindo capacidade de pesquisa, de resolução de problemas, de projetos, de trabalho em grupo, de análise, de síntese e de comunicação. As metodologias ativas buscam, também, o desenvolvimento da capacidade de observar, pensar, criar e se comunicar, fazendo descobertas em situação de parceria (McDONALD,2010).

Nos métodos tradicionais de ensino, o aluno está sempre em uma posição passiva no processo de aprendizagem, tentando absorver os conhecimentos e as experiências transmitidas pelo professor, e que são do professor. A utilização de aulas expositiva, onde o professor expõe o assunto e avalia os alunos a partir do conteúdo absorvido nas aulas e em estudo da matéria, é usual tanto por questões didático-pedagógicas tradicionais, como pelas econômico-administrativas. Com isso, utiliza-se da estratégia mais conhecida, econômica, flexível e rápida de transmissão de conteúdo, que ainda pode ser utilizada por qualquer profissional com domínio da matéria, mesmo não dispondo de profundos conhecimentos pedagógicos (GIL, 2005).

Em novos métodos de ensino, mais dinâmicos, o aluno participa como um agente ativo na aprendizagem, inserido em atividades dinamizadoras, que desenvolvem suas capacidades transversais, propiciando uma aprendizagem contínua e dinâmica. O principal papel do professor passa a ser o de ajudar o aluno a aprender, e não mais o de ensinar.

A metodologia ABP é caracterizada pelo uso de projetos do mundo real para encorajar os alunos a desenvolverem pensamento crítico e habilidades de desenvolvimento e solução de problemas, adquirindo conhecimento sobre os conceitos essenciais da área em questão. Segundo Ribeiro et al (2004), o método pode ser implementado em todo um curso ou como estratégia educacional parcial e até em disciplinas isoladas.

No método o aluno é exposto a situações motivadoras em grupos tutoriais, onde, através de um projeto, é levado a definir objetivos de aprendizado sobre os temas do currículo. Um dos fundamentos principais do método é ensinar o aluno a aprender, buscando conhecimento em meios de difusão variados. Com isso, além de se manter atualizado com o assunto, o aluno desenvolve agilidade para solucionar problemas e criatividade para explorar novos métodos de organização. Os resultados levam o aluno a uma independência maior, retém os conhecimentos adquiridos por mais tempo e desenvolvem uma postura de estudo Software Livre

2.2 Software Livre

A computação atualmente assume vários papéis. Compartilhar conhecimentos, estratégias e ferramentas de ensino são alguns deles. Atualmente é necessário que se observe a evolução destes recursos para que se possa inseri-los no desempenho da atividade de ensino e aprendizagem, no papel do professor e na postura do aluno diante dos avanços.

No momento atual já se percebe que o processo de informatização é irreversível, tanto na sociedade quanto na escola (MONNERAT, 2012). De acordo com Carvalho & Ivanoff (2010), a utilização de bases de dados e informações, comunicação e interação e construção de conteúdo são práticas que estão sempre presentes no processo de ensino e aprendizado com tecnologias de informação e comunicação.

O uso da tecnologia CAD (Computer Aided Design) gerou uma grande mudança na elaboração de projetos de engenharia, dadas as suas qualidades que não são encontradas nas formas manuais de desenho, como rapidez, eficiência e facilidade de revisões (JACQUES, 2003). Com relação ao ensino nos cursos de engenharia e tecnologia, seu uso abre oportunidades de uma visualização de objetos em 3 dimensões a partir de vistas ortográficas e de perspectivas.

Muitas instituições de ensino, principalmente as públicas, possuem recursos limitados para adquirirem softwares CAD, dado o seu alto custo, mesmo considerando licenças acadêmicas. Muitos alunos também não possuem condições para comprar esses programas e utilizá-los em suas próprias casas, o que facilitaria o aprendizado (CHENG & BARBOSA, 2007).

Para a redução dos custos com estes softwares CAD, propõe-se neste projeto o uso de softwares livres, gratuitos. O FreeCAD é um deles. Trata-se de um software multiplataforma para trabalhar com desenho técnico, em duas ou três dimensões, e que ainda possui interface gráfica para imprimir nas mais modernas e atuais impressoras tridimensionais. Além do FreeCAD, outros softwares como Blender e Google Sktech Up podem ser inseridos no projeto.

Sendo assim, o uso do computador na disciplina através de software livre, substituindo o papel e prancheta, pode ser inserido pela ABP, pois propõe mais independência ao aluno e ao projeto a ser desenvolvido.

3 A Aplicação da Metodologia

Este trabalho se justifica pela atual situação de complexidade envolvida na condução da disciplina de desenho técnico frente às necessidades empresariais e recursos tecnológicos aplicáveis, além da importância da pesquisa por metodologias de ensino utilizadas na evolução da qualidade educacional.

O avanço da tecnologia na aplicação de desenho assistido por computador e dos projetos em rede, de modo geral, é pouco explorado por professores e alunos na disciplina de desenho técnico.

Apoiado por esta justificativa, este estudo propõe como problema de pesquisa a seguinte questão: "O método aprendizagem baseada em projetos e a utilização conjunta de software livre é aplicável na disciplina de desenho técnico?" Esta questão norteadora ainda é apoiada pelas seguintes questões secundárias:

- Quais as principais adaptações necessárias para aplicar o método proposto na disciplina de desenho técnico?
- Os alunos percebem uma aprendizagem facilitada com o método proposto?
- Como outros docentes percebem a transição do método tradicional para o método proposto?
- Quais os principais obstáculos para a transição do método tradicional para o método proposto?

Através do desafio em contribuir com o aprimoramento de metodologias de ensino e aprendizagem, este trabalho tem como principal objetivo testar se o método de ensino baseado em projetos é aplicável a disciplina de desenho técnico. Além deste objetivo, ainda complementam o projeto:

- Apresentar um método baseado em projetos aos alunos participantes da pesquisa;
- Medir a aceitação de os alunos participantes da pesquisa quanto à aplicação do método, dinâmica e o potencial dentro do processo de aprendizagem;
- Comparar a percepção de docentes em relação ao confronto do método tradicional com o método baseado em projetos.

A partir destes objetivos, se forma o alicerce das decisões metodológicas para o levantamento de hipóteses:

- O método de ensino aprendizagem baseada em projetos é aplicável a disciplina;
- O uso de software livre favorece a prática da disciplina e melhora o aprendizado em sala;
- A combinação do método com o software livre coloca o aluno mais próximo aos desafios externos que estará envolvido na prática profissional;
- A aprendizagem por meio do método é mais consistente e aplicável;
- Os alunos apreciam a dinâmica do método;
- A principal dificuldade de aplicação do método são os problemas de relacionamento entre os membros dos grupos;
- Para implementar o método são necessárias adaptações aos diversos perfis de docentes.

A metodologia desta pesquisa segue o que está fundamentado por Gil (2002), que define pesquisa-ação como um tipo de pesquisa empírica concebida e realizada em associação com uma ação ou com a resolução de um problema coletivo, no qual os pesquisadores e os participantes estão envolvidos de modo cooperativo ou participativo.

A pesquisa é também quantitativo-descritiva, investigando de forma empírica a análise da avaliação do programa da disciplina e desenvolvida através de um estudo de avaliação de programa. Para Marconi & Lakatos (2002), é um estudo que procura os efeitos e seus resultados em um método específico relativo à educação.

A partir de uma população composta por alunos do curso Técnico em Química do Colégio Técnico de Lorena (COTEL) da Universidade de São Paulo (USP), a unidade de análise é constituída em um conjunto de alunos (aproximadamente 30 alunos) do primeiro ano. A escolha da unidade de análise é decidida por possibilitar a aplicação do método junto a alunos do próprio pesquisador, que de modo geral, não têm somente na pesquisa o principal instrumento de busca de melhorias. Este trabalho pode enriquecer o conteúdo por diversificar a metodologia de ensino aprendizagem já utilizado junto a alunos deste colégio.

O COTEL é vinculado à USP por meio da Escola de Engenharia de Lorena (EEL). É uma instituição de habilitação profissional de Técnico em Química e ensino médio, oferecidos de forma concomitante. Tem aulas em período integral (manhã e tarde), com duração de 3 (três) anos para obtenção de título de Técnico em Química.

O Técnico em Química é formado com um alto grau de conhecimento específico, constituindo mão de obra fundamental na indústria química, dirigindo sua função à análise química, no controle químico dos processos, meio ambiente, e outros setores de vital importância. Nas suas diversas especialidades, atua com uma visão atual e futurista, com competências técnico científicas, com capacidade de diagnosticar e solucionar problemas dentro de uma visão integrada entre as diversas e extensas áreas de atuação profissional.

Sendo o objeto de estudo deste trabalho, as variáveis da pesquisa são:

- A aplicação do método de aprendizagem baseada em projetos;
- As adaptações necessárias à aplicação do método;
- A percepção dos alunos quanto à dinâmica do método;
- A percepção dos alunos quanto às dificuldades exercidas pela aplicação do método;
- A percepção de docentes quanto à consistência da aprendizagem propiciada pelo método.

A principal instrumentação se dará por meio de coleta de dados por questionários aplicados aos alunos participantes após os mesmos serem submetidos ao método e a outros docentes da disciplina de desenho técnico que analisarão o programa. A identificação dos mesmos será opcional, assim como suas críticas e sugestões.

A distribuição das questões será definida como:

- Dicotômicas (responder opções de sim/não), com campos de aplicação a explicação da resposta opcional;
- Escala de ordenação (ordenar a importância) das características do método propostas;
- Propostas relativas ao método (concordar ou discordar, total ou parcial);
- Múltipla escolha (no qual escolhe apenas uma opção);
- Atribuição de nota para o método (critério de 0 a 10).
- Pergunta aberta (contribuição dissertativa).

Na implantação de uma metodologia baseada em projetos, o primeiro passo é a definição de um grupo tutorial, que é composto por:

- Docente Tutor, que tem como princípio o domínio do conteúdo de desenho técnico a ser aplicado, além de conhecer as etapas necessárias à implementação do método baseado em projetos. Neste trabalho, quem assume o papel é o próprio pesquisador. O Docente Tutor expõe o projeto aos alunos e é responsável em garantir o funcionamento do grupo e das discussões;
- Grupo de Trabalho, composto por 3 a 5 alunos, tendo um Coordenador de Grupo, responsável por garantir que a discussão do problema se dê de forma metódica e todos os membros participem da discussão e de um Secretário do Grupo, responsável pelas anotações de todas as atividades realizadas.

Este último garante a organização das mesmas, de forma metódica, respeitando as diretrizes do coordenador do grupo. Os papéis de coordenador e de secretário serão assumidos por todos os alunos em forma de revezamento.
- Grupo de Apoio, composto por docentes familiarizados com o método que se dispõem a contribuir na orientação dos alunos, nas diversas competências para o desenvolvimento do projeto

O projeto busca ser simples e objetivo para visualizar a proposta principal, além de motivador os alunos a discussão. É conduzido por etapas e concluído com êxito ao final da aplicação. Cada etapa do projeto compõe uma seção. Cada seção possui um tema, que é a estrutura mínima do conteúdo programático do currículo de desenho técnico e é apresentado aos alunos através do projeto. Os alunos devem entender o projeto e formular hipóteses, representando os conhecimentos que o grupo define como necessários para compor o projeto. Como recurso de aprendizagem, a disciplina de desenho técnico utiliza:

- Desenhos manuais iniciais: Lápis, papel, borracha, compasso, esquadro, dentre outros recursos básicos;
- Peças modeladas: Blocos, padrões de peça, esponjas de modelagem;
- Software livre: Freecad, Google Sketch Up, Blender;
- Hardware: As aulas de software acontecerão em salas de aula com computadores organizados por grupo (1 máquina para cada grupo);
- Elementos Mecânicos de Projeto: Aulas em oficinas de usinagem serão atribuídas em locais específicos da EEL/USP;

O currículo baseado em uma metodologia baseada em projetos objetiva apresentar os conteúdos de desenho técnico aos alunos de modo integrado e integrador de conhecimentos para formar um profissional preparado para ingressar em cursos de graduação em engenharia ou tecnologias. Deve preparar as situações nas quais os alunos deverão saber e dominar no exercício de suas atividades e de profissão.

Os alunos do projeto / da pesquisa serão submetidos ao método através das etapas:

- Em grupo, entendimento do projeto proposto procurando contextualizar a situação descrita em suas práticas profissionais;
- Identificação das etapas do projeto, necessárias a complementação do mesmo, assim como sua subdivisão de atividades;
- Formulação de hipóteses explicativas para o projeto;
- Formulação dos objetivos de aprendizado;
- Estudo individual dos assuntos levantados nos objetivos de aprendizado;
- Discussão do problema frente aos conhecimentos adquiridos nas etapas de desenvolvimento do projeto;
- Desenvolvimento de relatórios técnicos sobre o projeto;
- Apresentação dos grupos sobre as situações específicas do projeto e aula expositiva.

O desempenho de cada participante é medido pelos trabalhos do seu grupo como um todo, sendo que cada membro deve desempenhar seu papel de forma efetiva e responsável. Uma auto avaliação também ocorre ao final dos trabalhos, quando será solicitado que cada participante estipule uma nota para seu desempenho. Os resultados desta etapa são considerados na formulação da média final dos alunos.

Todos os passos serão desenvolvidos durante o desenvolvimento total do conteúdo da disciplina de desenho técnico (anual), com 80 horas/aula. Cada aplicação (aula semanal) refere-se a duas horas-aulas, considerando que as notas serão atribuídas de forma bimestral.

As principais atividades planejadas dividem-se em etapas ao longo de 12 meses de execução, que resultará em intercâmbio acadêmico, publicações e simpósio.

- Etapa I - Pesquisar o estado da arte dos temas relevantes como Metodologias de Ensino Baseadas em Projetos, Ensino do Desenho Técnico e Utilização de Software Livre no Ensino.
- Etapa II - Aplicar a pesquisa no desenvolvimento da disciplina de Desenho Técnico, no COTEL/USP. A aplicação iniciará no início do ano letivo de (Fevereiro de 2015) e terminará ao final do mesmo (Dezembro de 2015). O trabalho envolve a aplicação da metodologia de pesquisa-ação.

- Etapa III – Firmar um acordo de colaboração em pesquisa internacional.
- Etapa IV - Fazem parte das atividades resultados esperados:
    a) Organizar um evento com os alunos ao final do ano letivo envolvendo uma competição com os projetos gerados na disciplina;
    b) Participar de evento científico relevante, com apresentação de trabalho relacionado ao projeto;
    c) Submeter um artigo acadêmico a revista cientificamente relevante;
    d) Elaborar relatório técnico ao final do projeto.

O projeto contará com os seguintes recursos já disponíveis na EEL/USP:

- Software: Freecad;
- Hardware: Computadores disponíveis na EEL/USP;
- Instalações Físicas: Uma sala da EEL/USP (computadores) e salas de aula do COTEL/USP;
- Infra-estrutura de apoio para os bolsistas e eventuais colaboradores.
- Recursos bibliográficos: Bibliotecas e acesso dos periódicos da FEG/UNESP.

4 Conclusões e Implicações

Esta proposta pode representar uma significativa contribuição nos atuais processos de ensino e aprendizagem que são centrados na aprendizagem do estudante e ao aprimoramento de docentes. Os resultados ainda dependem da aplicação prática, mas podem proporcionar melhores condições para uma aprendizagem mais significativa e baseada as necessidades práticas. Num sistema de aprendizagem baseado em projetos, os alunos integram e aplicam os conhecimentos num projeto comum, onde desempenham um papel central na sua própria aprendizagem. Ao se concluir os dados da pesquisa, será possível analisar e compreender as percepções dos estudantes relativamente à metodologia e aos seus efeitos nos processos de ensino e aprendizagem dos alunos. Em geral, pode-se antecipar como resultados a interdisciplinaridade e articulação dos conteúdos da disciplina, o desenvolvimento de competências transversais, a avaliação formativa, o feedback, e uma postura de ensino centrada na aprendizagem do estudante, na autonomia e na flexibilidade. Contudo, ainda levantam-se ainda várias interrogações: estarão os docentes realmente preparados e dispostos a uma mudança para uma participação mais ativa por parte dos estudantes? Quais as condições necessárias para o desenvolvimento da metodologia? Estas entre outras questões ainda serão foco de debates e reflexões futuras na aplicação deste projeto. Sendo assim, este modelo é de extrema importância para os futuros profissionais, que desta forma, desde os primeiros passos da sua formação, buscam alternativas para resolução de problemas reais e soluções integradas.

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“Pop-Pop Boats" Competition as active learning approach using problem-solving techniques for students of engineering courses

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Abstract

The "pop-pop boat" race was developed in order to integrate knowledge and applications of basic disciplines, such as the concepts of speed, vectors, materials science, structures, among others, to the students in the first year of Engineering courses. Moreover, various skills and attitudes important in running a project (organization, management, teamwork and communication) are also developed from the beginning of the course. The project was developed in three stages. In the first stage, students built a standard boat model, using recyclable materials, candles and tubular copper wires. After construction, the tests were done in lanes of 2.30 m long and 0.25 m wide. The second step, consists in analyze the performance of each boat and through the construction of Ishikawa (Fishbone) Diagram, proposing solutions to improve the boat performance. The class was divided into groups. Each team have specific tasks (coordination, purchases, research and construction of the propellant, research and construction of the structure, final testing and documentation) for building another boat. In the third stage was held a competition between classes, which was taken into account the quality of construction, speed of the boat and the documentation.

Keywords: engineering education; project based learning; problem solution.

1 Introduction

Engineer Education faces a challenge: on one hand, the need for a strong technical background to enable the full correct professional performance and, on the other hand, the need for new skills and attitudes, such as ethics, citizenship, leadership, initiative, autonomy, good communication (oral and written), interpersonal skills and ability to work in groups, working on the creation of innovative products and processes.

The "pop-pop boat" competition was developed in order to stimulate the first years students in the importance of various points related to basic knowledge in engineering, such as concepts of speed, vectors, materials science, structures, among others. In addition, we also intend to develop, since the first years of the course, important skills and attitudes in running a project: organization, management, teamwork, communication (Van Hattum-Jansesen, 2012).

This action is part of the technique known as PLEE (Project-Led Engineering Education), an Active Learning technique which presents real challenges that require the student to seek solutions to situations (Weenk, 2012). The student develops the necessary skills (responsibility, initiative, teamwork, leadership) and, to search solutions, also rises the need to seek the necessary knowledge for the development of projects from the very need of the student (Fernandes et al, 2012). Thus, the teacher's role is no longer the main actor of the teaching process but a mentor or facilitator of the learning process (Campos, 2012).

Below are some theoretical principles that are involved in the project: operation of pop pop boat, analysis techniques and troubleshooting (Ishikawa - Fishbone- Diagram and Quality Control Method) and project management principles.

1.1 The ”POP POP” Boat

The pop pop boat is a simple heat engine containing a candle (or other heat source), a coil (capillary tube), and the structure of the boat itself, can be polystyrene, rigid paper, plastic, or any other buoyant material.

The propulsion of the boat is made by a thermal machine, consisting in a heat source (candle flame), with a temperature of about 1100 ° C (for common wax candle), a cold source (water in which the boat is that and is in contact with the outlet of the capillary) at room temperature. The capillary tube is filled with water, a portion is in contact with the flame of the heat source and its ends immersed in the water.

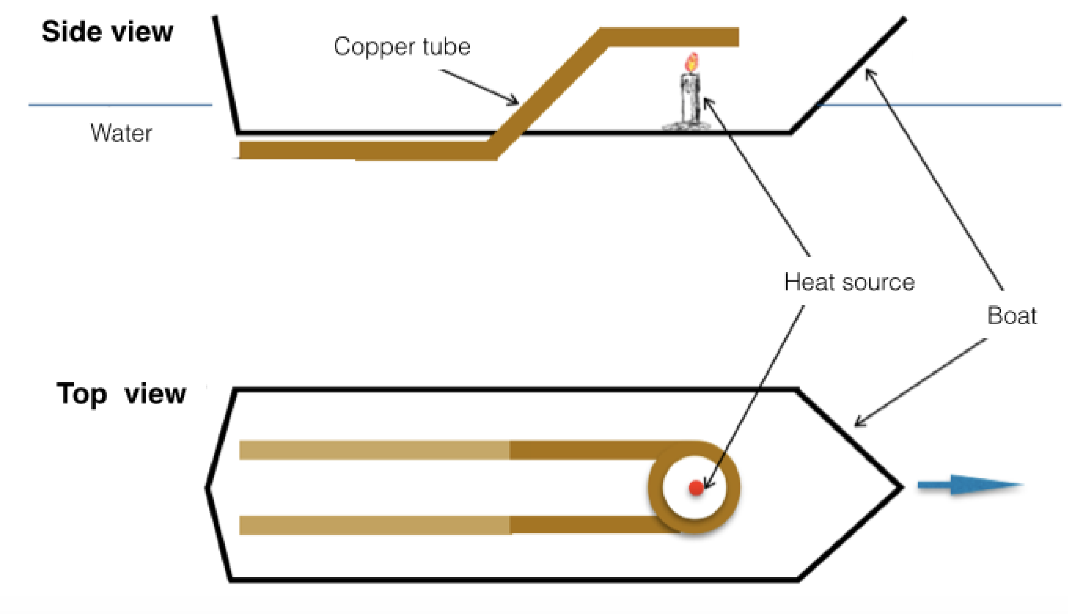

Figure 1: Representation of a typical “pop-pop" boat

The boat propulsion force comes from the expansion process obtained from the evaporation of water, the boat tends to move forward. With the fluid outlet at a higher temperature, this tends to condense on contact with the cold source (external water at the exit of the copper tubular wire). In this cooling, the drop in temperature and pressure causes the water back into the capillary, and start the cycle again.

1.2 Ishikawa Diagram

Originally proposed by Kaoru Ishikawa, chemical engineer, in 1943, also known as "Diagram of Cause and Effect”, "Fish Bone Diagram" or ”6M Diagram", the graph consists of a hierarchical structure in which potential causes and effects are indicated in given problem, assisting in problem analysis and improvement of that product or opportunity process.

1.3 M.A.P.S. (Method of Analysis and Problem Solutions)

M.A.P.S. is a Quality Control Method consisting of eight steps of a structured report to assist in solving more complex problems. The M.A.P.S. is based upon PDCA Cycle, DMAIC, Six Sigma and QC-Story Methods (De Mast, 2012). Applies to products, processes or services.

This script provides a way to solve problems that includes planning in the pursuit and implementation of solutions, later, the MAPS method will serve as an introduction to project management. The eight steps are:

- Define/ Recognize problem;
- Observe (and measure);
- Analyze;
- Plan (Action plan);
- Check and control (results);
- Replicate (standardize);
- Conclude.

2 Work Development

2.1 Initial assembly

In the initial class, students are divided into groups of up to six people and receive a drawing with the boat model and the necessary material to build it. After assembly, students verify the operation of the boat in lines 2.30 m long, 0.25 m wide. Each work group takes notes over the boat performance and develops an Ishikawa diagram (fish-bone) in order to identify the causes and analyze problems related to the construction and boat movement.

2.2 Ishikawa Diagram

The groups expose and discuss their particular analysis and then the entire class is asked to create a single boat that will represent it in an inter-class competition. Each boat acts as a different "test", the analysis of several boats in the same class brings up many problems that must be corrected in making the final boat.

The rules of competition were simple: the propulsion must be thermal and the boats must not be longer than 0.18 m. The result of competition take into account the velocity of the boat, quality of assembly and quality of final report.

2.3 MAPS

From the diagrams presented by the groups, we move to the Analysis Methodology and Troubleshooting (MAPS). The steps of the method are listed:

- Identify the core problem;
- Using the Ishikawa diagram, observe and write down five main causes noted by groups.
- Analyze how each of these causes can be treated.
- Now the class begin the Action Plan (fourth stage of MASP). For this, the class will be divided into workgroups. Each group - described in item 2.4- has a different role in the project.
- Tests and measurements were performed by workgroups (according to their role in project) during the development of the project.
- Coordination group keeps up with other groups verifying their work, results and controlling schedule and deadlines.
- After tests, the class decides the final model and that will be used in competition.
- A report, containing all costs, tests, reports of others groups and results is elaborated by the group responsible for this task and delivered for assessment.

The action plan

2.4 Project Development - Workgroups

- **Overall coordination**: this group is responsible for the work schedule, according to the deadlines. Integrates the actions of other groups. Monitors the work, so that deadlines are met.
- **Purchase of equipment**: responsible for making quotations, purchases and deliver requested materials. Are also responsible for collecting the money from the class as well as accountability.
- **Propellant research**: responsible for researching alternative of thermal machines. Must inform the purchasing group the material to be used and give to the assembly group all necessary instructions and diagrams. This documentation will also be passed to the report group.
- **Manufacture of propellant**: from research group's research, this group is responsible for assembling and testing propulsion.
- **Boat structure research**: responsible for researching alternative materials, and improvements in the boat's structure, must inform the purchasing group the material to be used and go to the assembly group all necessary instructions and diagrams. This documentation will also be passed to the documentation group.
- **Assembly of the boat**: from the research group's research, this group is responsible for assembling and testing of propulsion.

- **Documentation / report:** Receive all the research material and costs. Write the final report. Being first years students, it is important to provide a template (a report model) to guide the document production.
- **Testing and final assembly**: team responsible for testing and final assembly. Tracks that will be used in competition, are available for tests.

3 Results

3.1 Students perception on the project

In an evaluation section, after the end of project, about 50% of students pointed out that learning how to work in teams was the most important ability developed in this project. Organization and motivation were also cited (about 20% each). According to students, running a project requires division of tasks, organization, participation and meeting deadlines.

Coordination group also mentioned difficulties in getting every students to participate actively, perhaps because the number of students (average 60 people per class).

According to students, the main flaws in this phase of work was communication between the groups and the fact that not every students collaborate. The communication has been noted as a problem because the actions of each group depend on the others groups with consequences for all groups. This finding of the students was very important because communication is, in fact, a critical step in large projects and the students' perception of this fact should have positive consequences in the coming projects and probably in future professional activities.

3.2 Ishikawa Diagrams

Another important concept developed in this project was troubleshooting analysis. Posterior assessment showed good results in making Ishikawa Diagram. As we said before, the first diagrams were made in small groups and then discussed and remade with the whole class. An example of diagram, built by students, is showed in figure 2:

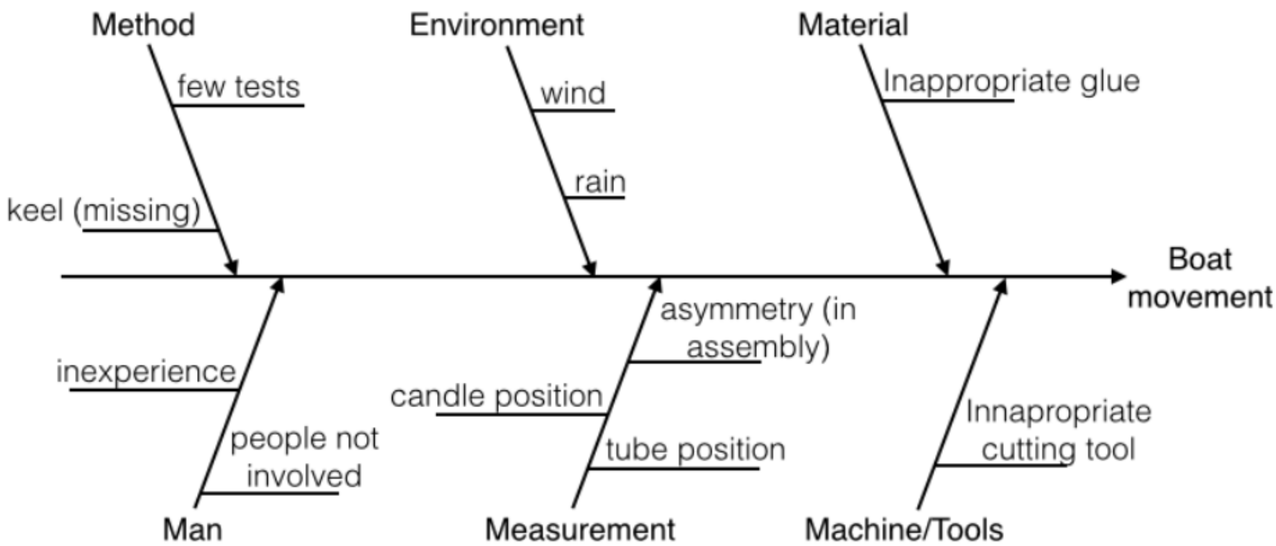

Figure 2: An example of students Ishikawa Diagram analyzing problems in the boat movement

3.3 "Hands-on": assembly and objective results

The initial assembly was made and tested in lanes 0.25 m wide and 2.30 m long, with start and end tags, making a real path of 2.10 m. In the initial assembly, the boats crossed tracks in an average time of about 25.2 s. The best time was 13.1 s.

After the modifications on the boats, proposed and implemented by the students, the average time was 19,8s and the best time was 8,9s. The improvement of times (about 20% on average) and the quality of assemblies show that the work of analysis (Ishikawa and MAPS) were effective.

Table 1: Comparison between initial and final performances

Initial assembly	25.2	13.1
Final assembly	19.8	8.9
Performance improvement (%)	21.4	32.1

3.4 Reports

A report template was provided to students. One of the working groups was responsible for preparing the class report. As these are the first grade students, this model is important to guide them in performing this task, since most don't have enough experience to do so.What we observe is that the quality of reporting was higher than expected from first-years.

4 Conclusions

Objective results were analyzed by improvement of time of route, by quality of final assemblies and reports. Subjective results were observed by debriefing section with students and teachers.

Teachers also identify a shift in their role when working in projects. They also pointed out the need of more effective support (more training and preparing sections) in order to make more effective and successful the results of learning process. Teachers cited an improvement in relationships between colleagues and with students. Teachers teamwork is also important in project implementation.

The increasing of 20% on boat velocity and creative solutions on assemblies shows that the competition helps to stimulate student for better results. Teachers were very impressed about good report quality, considering first-years students.

Students motivation and involvement were pointed out both by teachers and students as positive aspects. Communication and team work also were market as important issues addressed in this project.

Posterior assessment showed a good comprehension of Ishikawa Diagrams constructions and MAPS tools. Both were developed based on the results of first assemblies and had as objectives the construction of a competition boat. As a learning method, that seems to be more effective than a lecture about the themes. Perceptions suggest a deep-level learning when students run projects and link theory to practice to solve problems.

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The Impact to Implement a Model of Discipline in 100% PBL (Project Based Learning

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Abstract

This article proposes to open a discussion on the impact, implementation, difficulties and successes in implementing the PBL methodology in civil, electrical, electronic and mechanical engineering courses. Thinking about how these professionals are leaving higher education and reaching the labor market and what skills and competencies are required, the current higher education cannot contemplate models only exhibition class and should be concerned with an integral education of the student. The Salesian University Center - UNISAL LORENA has the pedagogic proposal to work with innovative methodologies, focusing on improvements in the learning process of their students. In 2012, was created the LMI (Innovative Methodologies Laboratory), which focuses seek and know various techniques of active methods and bring them the reality of our courses and our students, enabling even teachers to be multipliers such methodologies. The methodologies used in 2013 and 2014 were the Peer Instruction (from the model applied at Harvard by Professor Mazur), Team Based Learning (from the model applied in Central Missouri University by Professor Larry Michaelsen) and the Writing Across the Curriculum (from the model applied at MIT, by Professor Jennifer Craig). In the second sementre 2014, the PBL methodology (Project Based Learning, from the teacher's model Jonathan Stolk, applied in Olin College) was implemented, which was crafted in Fluid Mechanics discipline in courses in Civil Engineering, Electrical, electronics and Mechanics. The PBL methodology was fully utilized in the discipline and was conducted a previous study, the period of one semester by a board in order to perform the adaptation of the traditional menu to the new model. In addition to increased quality of learning through the development of skills required by the labor market, such as project management, individual goals are the teamwork, the increase in interpersonal relationships, communication development, which complements the student's education.

Keywords: active learning; teamwork; projects; technical applications.

O Impacto ao implementar um modelo de disciplina em formato 100% PBL (Project Based Learning)

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Resumo

Este artigo se propõe a abrir uma discussão sobre o impacto, as dificuldades e sucessos na implementação da metodologia PBL em cursos de engenharia civil, elétrica, eletrônica e mecânica. Pensando em como esses profissionais estão deixando o ensino superior e alcançando o mercado de trabalho e que habilidades e competências são necessárias, o ensino superior atual não pode contemplar apenas os modelos de classe expositiva e deve se preocupar com uma educação integral do aluno. O Centro Universitário Salesiano - UNISAL LORENA tem a proposta pedagógica de trabalhar com metodologias inovadoras, com foco em melhorias no processo de aprendizagem de seus alunos. Em 2012, foi criada a LMI (Laboratório de Metodologias Inovadoras), que se concentra buscar e conhecer várias técnicas de métodos ativos e trazê-los à realidade de nossos cursos e nossos alunos, permitindo aos professores serem multiplicadores dessas metodologias. As metodologias utilizadas em 2013 e 2014 foram a PEER INSTRUCTION (a partir do modelo aplicado em Harvard pelo Professor Mazur), Aprendizagem Baseada em Equipe (a partir do modelo aplicado na Universidade de Missouri pelo professor Larry Michaelsen) e a escrita através do currículo (a partir do modelo aplicada no MIT, pela professora Jennifer Craig). No segundo sementre de 2014, a metodologia PBL (Aprendizagem Baseada em Projetos, a partir do modelo do professor Jonathan Stolk, aplicado em Olin College) foi implementado, e trabalhado na disciplina de Mecânica dos Fluidos nos cursos de Engenharia Civil, Elétrica, Eletrônica e Mecânica. A metodologia PBL foi aplicada totalmente na disciplina e foi realizado um estudo anterior, pelo período de um semestre por um conselho, a fim de realizar a adaptação da ementa tradicional para o novo modelo. Além do aumento da qualidade da aprendizagem através do desenvolvimento de habilidades exigidas pelo mercado de trabalho, tais como gerenciamento de projetos, trabalho em equipe, o aumento nas relações interpessoais, desenvolvimento da comunicação, que complementa a educação do aluno.

Keywords: aprendizagem ativa; trabalho em equipe; projetos; aplicações técnicas.

1 Introdução

Vivemos hoje em um mundo globalizado , onde as empresas têm uma grande necessidade de aprimorar os seus produtos e serviços e dar respostas rápidas às exigências do mercado de trabalho. Abordagens criativas para problemas , "pensar fora da caixa", assim como ideias inovadoras para satisfazer os clientes são uma necessidade cada vez maior (Nair, Patil, & Mertova, 2009).

O rápido desenvolvimento científico e tecnológico que estamos presenciando, exige a necessidade de propiciar uma formação que estimule a busca contínua do conhecimento e aprimoramento. Um engenheiro que não se atualiza, em pouco tempo, perde a sua competitividade para atuar no mercado de trabalho.

O economista Jeffrey D. Sachs, diretor do Programa do Milênio das Nações Unidas, diz que os desafios da América Latina são a desigualdade social, a estagnação econômica e choques na interação entre o homem e a ecologia. Somente a Engenharia e a tecnologia podem enfrentar estes problemas, mas, ao contrário da Ásia, a América Latina não promoveu políticas voltadas a impulsionar o desenvolvimento tecnológico. A este cenário de insuficiência quantitativa de engenheiros e mesmo de estudantes de engenharia para fazer frente às necessidades do País de incorporar tecnologia, soma-se o problema de qualidade que vem afetando boa parte da educação superior, herdeira final das deficiências que afetam os níveis de educação precedentes (Inova Engenharia, 2006)

O modelo de ensino tradicional, onde o professor é o principal agente do conhecimento, passando informações para o aluno, já está ultrapassado e não prepara um profissional de maneira adequada para ser capaz de atender as necessidades de um mercado de trabalho tão dinâmico.

Surge a necessidade de termos um pensamento diferenciado na comunidade acadêmica para que possamos formar alunos/profissionais que sejam capazes de promover ações e realizar investigações, trabalhar em equipe, gerir problemas e apresentar soluções. Habilidades profissionais envolvem conhecimentos técnicos e capacidade de desenvolver e buscar novos conhecimentos bem como a capacidade de desenvolver atividades seja de pesquisa ou de projetos em grupos (Mohan et al., 2010).

Para formar um profissional que faça a diferença no mercado é necessário estruturar um curso e ensinar de maneira diferenciada.

Assim, O Centro Universitário Salesiano – UNISAL LORENA tem como proposta pedagógica trabalhar com metodologias inovadoras, objetivando melhorias no processo de aprendizado de seus alunos.

Em 2012, criou-se o LMI (Laboratório de Metodologias Inovadoras), cujo foco é buscar e conhecer novas técnicas de metodologias ativas e trazê-las a realidade dos nossos cursos e nossos alunos, capacitando inclusive, professores para que sejam multiplicadores de tais metodologias.

Figura 1: Logotipo do Laboratório de Metodologias Inovadoras

As metodologias utilizadas em 2013 e 2014 foram o Peer Instruction (estudado a partir do modelo aplicado em Harvard, pelo Professor Eric Mazur), o Team Based Learning (estudado a partir do modelo aplicado na Universidade Central Missouri, pelo Professor Larry Michaelsen) e o Writing Across the Curriculum (estudado a partir do modelo aplicado no MIT, pela Professora Jennifer Craig). No segundo semestre de 2014, foi implementada a metodologia PBL (Project Based Learning, estudada a partir do modelo do professor Jonathan Stolk, aplicado em Olin College), na disciplina Mecânica dos Fluidos, matéria do ensino básico das engenharias do UNISAL, nos cursos de Engenharia Civil, Elétrica, Eletrônica e Mecânica.

2 Motivação

O surgimento da ideia de se trabalhar com a metodologia PBL, na disciplina mecânica dos fluidos, deu-se ao observar as dificuldades dos estudantes de engenharia em entender o conceito teórico a ser estudado e relacionálos com aplicações práticas, o que se traduzem em pessoas despreparados para enfrentar o mercado de trabalho, evidenciando o despreparo em utilizar habilidades simples, ou *"soft skills"*. Segundo Maximiano (2004) "Competências são conhecimentos, habilidades e atitudes necessárias para uma pessoa de realizar atividades". O mercado brasileiro exige dos profissionais de engenharia um profundo e sólido conhecimento interdisciplinar em competências técnicas para gerenciamento de projetos, condução e liderança de equipes, cujas competências lhes faltam.

No consórcio STHEM Brasil – Unisal, em 2014, através da interação com o Professor Jonathan Solk, de Olin College, desenvoulveu-se uma discussão sobre aplicação 100% da metodologia na área de exatas de maneira a motivar o aprendizado discente.

Focando em motivar o aluno a pensar e trabalhar de uma maneira diferenciada, implementou-se na unidade um novo espaço de criação, projeto e design, inserido no ambiente de laboratórios integrados das engenharias, onde o aluno está focado em criar e desenvolver habilidades "hands on".

Figura 2: Laboratório de Criação, Projeto e Design

3 Metodologia

Descreve-se de maneira sucinta, a maneira a qual a metodologia foi implementada e os procedimentos metodológicos utilizados durante o processo.

Segundo o modelo de Olin College, para desenvolvermos e implementarmos o Project Based Learning em uma disciplina e obter engajamento dos alunos deve-se:

- Considerar diferentes objetivos que podem ser atingidos com projetos
- Ter atividades para envolver o aluno e levá-lo a atingir as metas.
- Conduzir as atividades a um produto (exemplo um modelo de negócios).
- Avaliar através do desenvolvimento de um processo contínuo.

Seguindo esses princípios, a metodologia PBL foi implementada integralmente na disciplina, tendo sido realizado um estudo prévio, no período de um semestre, por um colegiado a fim de realizar a adaptação da ementa tradicional ao novo modelo, que tem como etapas:

- Levantamento e estudo da ementa original
- Divisão da Ementa em três grupos, focando a aplicação de projetos diferenciados
- Definição e divisão de conceitos chaves por grupo
- Definição dos projetos a serem desenvolvidos e estudados durante o semestre
- Elaboração de um cronograma de atividades a serem cumpridas pelo aluno.
- Processo de Avaliação

Foi necessário desenvolver uma estratégia de planejamento e comunicação clara com os alunos para que houvesse entendimento sobre o paradoxo de se buscar conhecimento através da curiosidade, do trabalho em equipe em detrimento às aulas expositivas, único processo conhecido, difundido e culturalmente disseminado no Brasil.

4 Desenvolvimento e Aplicação do Projeto

Podemos citar que entre as dificuldades enfrentadas, a maior se deu na etapa do desenvolvimento do projeto, a transição do modelo, a passagem do sistema de ensino aprendizado baseado na ideia de transmissão do conhecimento para o sistema de ensino aprendizado baseado no desenvolvimento de habilidades e competências, pois tanto aluno, quanto professor, estão acostumados ao modelo passivo e torna-se difícil tirá-los dessa zona de conforto exigindo paciência e persistência ao qual, o professor tem um papel fundamental, pois deixa de ser o centro das atenções e passa a exercer a função de tutor, guiando e estabelecendo o caminho a ser trilhado pelo aluno para que ele possa obter resultados práticos.

A natureza interdisciplinar da aprendizagem baseada projeto, especialmente nos casos em que for aplicado como um todo a filosofia curricular, os professores são obrigados a trabalhar em conjunto e desenvolver um ambiente favorável para a colaboração (Fernandes et al., 2009)

Dessa maneira, para a implementação do Projeto foi necessário um planejamento de três meses, entre os coordenadores das engenharias, realizado no semestre anterior a implementação da disciplina no modelo PBL, para estudar a ementa da Disciplina Mecânica dos Fluidos e transformá-la em três projetos a serem desenvolvidos pelos alunos no decorrer do semestre. O fator chave nesse momento foi estabelecer critérios para que os projetos abrangessem a maior parte dos conceitos envolvidos na ementa, sem que houvesse a necessidade de envolver todos os tópicos. importante focar os conceitos principais, pois ao trabalhá-los, implicitamente o aluno necessita de conhecimentos que abrangem os conceitos mais simples. Os projetos escolhidos foram: Princípio de Pascal, Princípio Hidrostático de Arquimedes e Número de Reynolds.

Utilizou-se um ambiente virtual de aprendizado (MOODLE – Ambiente institucional), no qual o aluno obteve informações sobre textos, vídeos, artigos. Nesse ambiente, o aluno pode se guiar em busca de orientações técnicas e também acompanhar seu desenvolvimento na disciplina, durante o decorrer do semestre.

Figura 3: Projetos Desenvolvidos

Não menos importante, foi estabelecida para esta disciplina uma forma de avaliação sistemática mista (grupo e individual) que permitiu estabelecer critérios através dos projetos e estudos apresentados.

A avaliação em grupo deu-se através do desenvolvimento e entrega dos projetos, onde os alunos foram acompanhados durante o processo e questionados na apresentação e entrega do modelo físico. Avaliações individuais foram trabalhadas a cada aula presencial através de modelos de trabalhos desenvolvidos e pesquisas realizadas.

A figura 4 mostra o modelo de auto avaliação dos alunos e o modelo de avaliação dos projetos entregues

Como vocês – toda a equipe – se auto avaliam com respeito aos critérios. Marque um X no emotion que mais se aproxima do julgamento de vocês.

Como está a qualidade dos nosso trabalho? (Aproveitem para "dar uma olhada nos trabalhos das demais equipes")					
Como nos sentimos acerca do nosso envolvimento (engajamento) com o projeto					
Protótipo construído; como ficou?					
E sobre a nossa capacidade de planejamento e coordenação?					
Como foi o relacionamento do nosso grupo?					
Adquirimos conhecimentos?					

	Critérios	Nota (0 a 10)
Apresentação	Comunicação	
	Postura	
	Participação dos membros	
Protótipo	Qualidade e esmero na construção	
	Criatividade	
	Relevância	
Relatório	Fundamentação Teórica	
	Dados e cálculos do protótipo	
	Reflexão e análise crítica	
	Formatação e organização da estrutura	
	Adequação aos objetivos	

Figura 4: Tabelas de Avaliação

Observou-se uma maior participação dos alunos na disciplina, através do aumento de presença em sala de aula comparativamente a aulas ministradas na mesma disciplina fazendo uso da metodologia de ensino tradicional. Notou-se também um maior engajamento e curiosidade do aluno na busca por conceitos e formas de sua aplicação. trazendo questionamentos para a sala de aula.

Ao compararem os projetos apresentados com os demais projetos entregues em turma e entre cursos, os alunos se sentiram desafiados, motivando-se a aprimorar seus trabalhos, com isso houve uma superação na qualidade dos projetos e relatórios apresentados.

"Está bem claro que a aprendizagem ativa ajuda os alunos a se envolver em estratégias de pensamento de alto nível e desenvolver habilidades cognitivas melhoradas" (Stolk, 2014).

O gráfico abaixo indica a nota média dos curso no segundo semestre de 2014, quando aplicou-se o PBL na disciplina Mecânica dos Fluidos

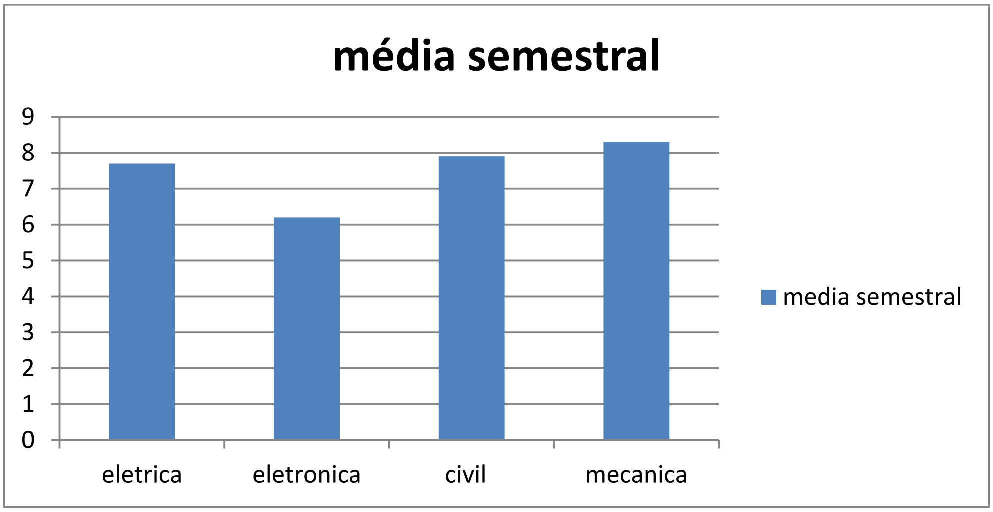

Figura 5: Gráfico da nota média semestral dos cursos na disciplina Mecânica dos Fluidos utilizando PBL

Se compararmos as médias do semestre anterior, trabalhado de maneira tradicional com o qual aplicamos PBL, podemos observar que houve um aumento na média final, levando a conclusão de que a metodologia ativa tem um aumento na aprendizagem efetiva do aluno.

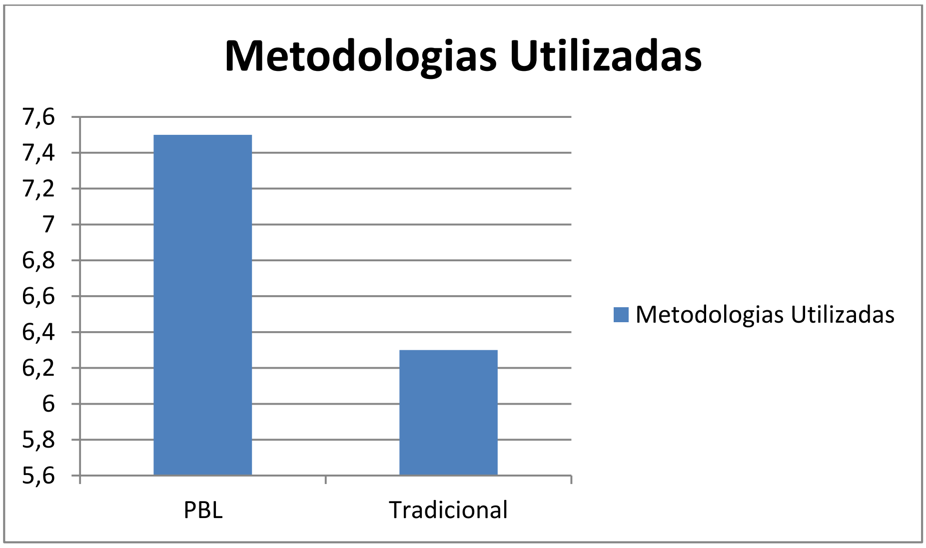

Figura 6: Gráfico Comparativo das Metodologias

Atualmente a metodologia de PBL está inserida no Laboratório de Metodologias Inovadoras do Unisal Lorena – LMI, que possibilita difundir e processo de aprendizado ativo entre professores, através de treinamento e ainda manter um estudo das técnicas da metodologia de maneira a estar adequando os processos às necessidades dos cursos.

5 Conclusão

A quantidade e velocidade de informação as quais temos acesso hoje, associada a facilidade que a tecnologia nos traz, possibilita uma busca diferenciada pelo conhecimento. Com isso torna-se imprescindível a substituição do modelo de aprendizado clássico pelo modelo de metodologias ativas, onde o aluno sai do papel passivo e se torna ativo, responsável por atingir diferentes níveis de aprendizado.

Essas metodologias agregam valores ao conhecimento, auxiliando no desenvolvimento de competências e habilidade exigidas no mercado de trabalho.

Os resultados apresentados nas figuras 5 e 6 mostram a evolução e o ganho do aprendizado, quando se trabalha uma metodologia ativa no ensino.

No sistema de ensino superior brasileiro já se percebe mudanças com relação às práticas de ensino.

O PBL (Project Based Learning) aparece como uma metodologia que desafia e motiva o aluno e estar criando e inovando em beneficio próprio.

Das dificuldades enfrentadas, destaca-se o esforço no sentido de quebrar paradigmas do aluno enfrentar um novo método de aprendizado, que se diferencia de tudo a que ele foi acostumado em toda sua vida acadêmica. Um desfio que vale a pena.

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Student Projects as a Resource for Improving Teaching of Telecommunications Engineering

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Abstract

In this paper we describe and analyze the acquired experience in based project learning implementation with students of Telecommunications engineering in National Autonomous University of Mexico. The projects were developed in the last year of study of the career. Our goal is that students obtain skills in solving practical engineering problems, in order they be able to achieve specific results in an engineering problem. We present technical and education results of the projects.

Keywords: engineering education; telecommunications engineering; project based learning.

Proyectos de Estudiantes como Recurso para Mejoramiento de Enseñanza de la Ingeniería en Telecomunicaciones

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Abstracto

Se describe y se analiza la experiencia adquirida en la implementación de algunos proyectos prácticos de los estudiantes, en la enseñanza de la Ingeniería en Telecomunicaciones en la Universidad Nacional Autónoma de México. Los proyectos fueron desarrollados en los últimos años de estudio de la carrera, con la finalidad de que los estudiantes obtengan habilidades en la solución de problemas prácticos de ingeniería, para que ellos sean capaces de alcanzar un resultado específico de ingeniería. Se presentan algunos resultados técnicos y educativos de los proyectos

Palabras clave: enseñanza de ingeniería; ingeniería en telecomunicaciones; aprendizaje basado en proyectos.

1 Introducción

Muchas universidades mexicanas emplean el aprendizaje basado en asignaturas esencialmente teóricas, como forma tradicional de enseñanza; la enseñanza de la Ingeniería: la ingeniería mecánica, la ingeniería industrial, los procesos de manufactura, la minería, la ingeniería petrolera, la electrónica, se realizan con materias que tienen prácticas de laboratorio o prácticas de campo. Particularmente, en la carrera de Ingeniería en Telecomunicaciones, impartida en la Facultad de Ingeniería de la Universidad Nacional Autónoma de México (FI-UNAM), cerca de 40% de las asignaturas de la carrera cuentan con un laboratorio para complementar el proceso de aprendizaje de los alumnos. La incorporación de laboratorios para todas las asignaturas de la carrera, prácticas de campo, proyectos de fin de carrera y los trabajos de tesis prácticos se ven limitados por el número de horas-clase, personal académico, espacio y recursos disponibles.

1.1 Motivación

La preocupación por la preparación óptima e integra de los estudiantes en un contexto real existe en la FI-UNAM. En particular, la academia considera un relativo aumento de actividades prácticas mediante la implementación de algunas pedagogías modernas, para que los alumnos adquieran una mejor habilidad de desarrollar sus actividades profesionales de ingeniería en los entornos del mundo real.

Un paso en esta dirección consistió en la implementación de la técnica didáctica de Aprendizaje Orientado a Proyectos, AOP (en el idioma Inglés: Project Based Learning, PjBL) en nuestra carrera. El AOP descrito por Knoll (1997), Kolmos, Fink y Krogh (2004) y Barge (2010) y en las referencias bibliográficas en estos trabajos, consiste en que los estudiantes construyen su aprendizaje mediante la planeación y desarrollo de proyectos tangibles aplicados a una situación o problemática real. Esta técnica surgió en las universidades europeas como una búsqueda para mejorar la calidad de los egresados. La Universidad de Aalborg en Dinamarca fue pionera en esta técnica didáctica, el concepto de AOP en esta Universidad esta descrita por Kolmos, Fink, y Krogh (2004), Barge (2010) y en las referencias bibliográficas en estos trabajos. Posteriormente otras universidades aprovecharon esa experiencia y la adoptaron a sus entornos.

De acuerdo con datos existentes, el AOP permite que el alumno:

- Sea responsable de su propio aprendizaje.
- Asuma un papel participativo y colaborativo en el proceso a través de ciertas actividades.
- Tome contacto con su entorno.

- Se comprometa en un proceso a través de la reflexión con lo que hace.
- Desarrolle la autonomía.
- Utilice la tecnología como recurso útil para enriquecer su aprendizaje.

Los principales conocimientos existentes sobre la técnica AOP se pueden resumir en:

- La elección de alcance, duración y complejidad del proyecto es responsabilidad de los profesores. Dependiendo de la ubicación del curso en el mapa curricular de la carrera, el grado de control del profesor y la autonomía del estudiante pueden variar.
- El proyecto debe ajustarse a temas contenidos dentro del programa de estudios de cada carrera. Es necesaria una secuencia y continuación apropiada del proyecto.
- El proyecto requiere de una planeación del proceso de trabajo. El proyecto del estudiante se desarrolla a través de fases, diferentes habilidades y de conocimientos.
- Es necesario tener suficiente tiempo para iniciar, acostumbrarse a otros miembros del equipo, hacer un plan de actividades, conseguir información, y darle solución al problema.
- El proyecto debe ser una unidad continua y lógicamente consistente.
- El tema y contenido del proyecto debe ser apropiado para estudiantes que trabajan en equipos (de 3 a 8 estudiantes aproximadamente).
- Debe delimitarse la extensión del proyecto acorde al modelo elegido y objetivos deseados.
- El proyecto debe permitir contribuciones desde una perspectiva propia del estudiante.
- El proyecto debe permitir aprovechar conocimientos o temas previos y desarrollar habilidades específicas.
- El proyecto debe permitir separar los problemas en tareas para cada miembro, manteniendo una idea del todo.
- El proyecto debe formularse de forma concreta, compleja y de un nivel considerable, además, debe indicar claramente lo que se desea del procedimiento y de la aproximación del problema.
- El proyecto debe incluir criterios para evaluar los resultados del grupo desde un principio, e informar acerca del reporte, límites, facilidades, etc.

Se consideran que el AOP proporciona las siguientes ventajas para el estudiante:

- Adquiere capacidad de autoaprendizaje.
- Se prepara para el trabajo en grupo.
- Adquiere experiencia en la elaboración de los reportes coherentes y bien estructurados.
- Adquiere elementos para la planeación y administración del tiempo en forma eficiente.
- Brinda un puente entre su proceso formativo y la experiencia profesional.
- Se desarrolla el hábito de un trato profesional.
- Se prepara para la vinculación con la industria.

Por otro lado, la Academia obtiene las siguientes ventajas:

- Aumento en la demanda de empresas por este tipo de egresados.
- Mayor vinculación con la industria.
- Ventaja competitiva de los egresados al incorporarse al trabajo profesional.
- Aumento en la matrícula.
- Aumenta el prestigio ante la comunidad.

Condiciones para implantar el AOP reconocidas en las fuentes bibliográficas:

- Determinar que habilidades y actitudes de la carrera son apreciadas en el entorno empresarial (que den ventajas competitivas).
- Revisar cuidadosamente el programa de estudios de cada carrera, desde el punto de vista de la implantación de AOP.

- Definir cursos o materias a involucrarse en el AOP.
- Seleccionar los niveles de complejidad de proyectos para cada plan de estudios.
- Escoger entre diversas estrategias de implementación.
- Establecer políticas claras en la administración, evaluación y acreditación de los proyectos.

El análisis de los datos existentes sobre la técnica de AOP nos lleva a la conclusión que esta técnica didáctica tiene un gran potencial, pero esta técnica debe ser adaptada de forma inteligente a condiciones específicas de cada universidad y carrera. Las primeras preguntas que enfrenta la academia al intentar implementar el AOP son:

- ¿Cómo acomodar esta técnica en condiciones particulares de nuestra carrera?
- ¿Cuáles son las formas óptimas de su implantación en nuestras condiciones?
- ¿Qué tipo de proyectos serán eficaces en el mejoramiento de aprendizaje de nuestros estudiantes?

A continuación se describe y analiza la experiencia adquirida en la implementación del AOP en una forma pragmática y limitada en el marco de una sola asignatura Sistemas de Comunicaciones Ópticas de la carrera de Ingeniería en Telecomunicaciones de la Facultad de Ingeniería de la UNAM durante los últimos seis años; esto en la espera de que nuestra experiencia será de utilidad en la implementación de esta técnica didáctica en carreras vecinas de ingeniería. El objetivo educativo principal de implementación de AOP fue que los estudiantes obtengan habilidades en la solución de los problemas prácticos de ingeniería, para que ellos sean capaces de alcanzar un resultado específico de ingeniería.

2 Forma de Implementación de los Proyectos

Los proyectos fueron implementados dentro de una sola asignatura Sistemas de Comunicaciones Ópticas, debido a la falta de experiencia y recomendaciones en la bibliografía existente sobre la forma y extensión de introducción del AOP en condiciones de la carrera de Ingeniería en Telecomunicaciones en universidades o institutos tecnológicos. Por esto, nos faltan consensos en la academia sobre las necesidades de cambio; según Lamancusa (2006) ésta es una situación que se presenta en otras universidades también.

La asignatura de Sistemas de Comunicaciones Ópticas se imparte en el octavo semestre de la carrera. Esta asignatura de 64 horas es subsecuente a otros, tales como: Circuitos Eléctricos, Diseño Digital, Comunicaciones Digitales, Tecnologías para el Procesamiento Digital de Señales, entre otros; el contenido de estas asignaturas nos sirvió como base para la elección del proyecto a desarrollar.

Algunos temas tratados en la asignatura Sistemas de Comunicaciones Ópticas son:

- Propagación de la luz en medios naturales y artificiales (guías de onda),
- Fuentes ópticas y foto detectores,
- Transmisores y receptores ópticos,
- Sistemas ópticos de comunicaciones.

La asignatura se complementa con un laboratorio (32 horas de trabajo para los estudiantes) enfocado en el manejo práctico de fibras ópticas (inspección, corte, empalme) y su caracterización (atenuación total, apertura numérica), etc.

3 Metas

Las metas a lograr fueron las siguientes:

- Lograr que los alumnos adquieran una mayor y mejor habilidad de desarrollo de actividades y proyectos reales de ingeniería, asignados en forma general sin cualquier instructivo y sin sugerencias de pasos a seguir, con la finalidad de poder trabajar en entornos similares del mundo real.

- Lograr que los alumnos sean capaces de aprender de forma autónoma y construir su propio conocimiento por medio de auto-aprendizaje, para poder solucionar los problemas no vistos en el marco de asignaturas y temas cubiertos por el plan de estudios.

Lograr que los alumnos adquieran una mayor y mejor habilidad de trabajar en grupos, mediante el desarrollo de diferentes roles en el grupo, para ser eficaz en el entorno real laboral.

4 Selección del Proyecto

Probamos en forma práctica diferentes temas para los proyectos: Desarrollo de un enlace de fibra óptica, una alarma óptica, un sensor óptico, etc. Después de probar diferentes temas de proyectos, encontramos que el desarrollo de un lector de código de barras (Figura 1) fue el proyecto más eficaz en la obtención de nuestro objetivo principal educativo.

Figura 1: Ejemplo de código lineal de barras

De acuerdo con la opinión de los profesores y estudiantes, las razones de éxito de este proyecto en comparación con los demás fueron:

- Este dispositivo (mostrado en forma general en la figura 2) integra elementos y subsistemas que han sido estudiados previamente por los alumnos de forma separada, tales como: óptica, electrónica, procesamiento analógico y digital de señales, y la transmisión de datos.
- Los estudiantes están bien familiarizados con las funciones del lector. Los lectores de código de barras se usan para leer la barra codificada (mostrada en la figura 2) en tiendas, almacenes, oficinas e industria.

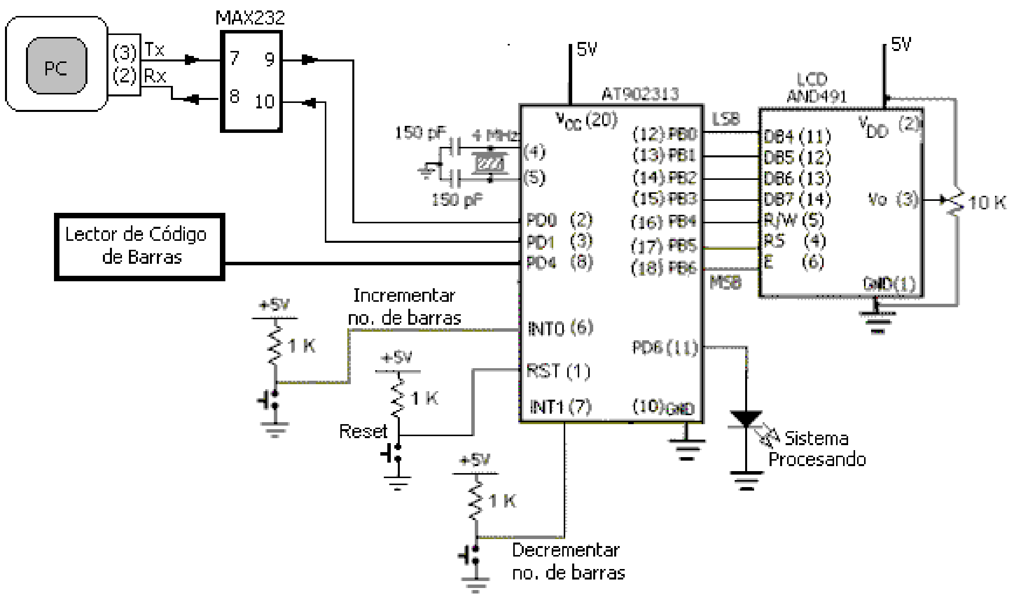

Figura 2: Diagrama eléctrico de un lector de código de barras

- Existe una variedad de soluciones alternativas para su implementación.
- Los lectores de códigos de barra son relativamente baratos, por esto la implementación práctica de un lector funcional es totalmente accesible para los estudiantes.

5 Contenido del Proyecto

Los estudiantes tenían que desarrollar una variante funcional de un lector de código de barras, probar y optimizar su funcionamiento, desarrollar y redactar un reporte, y demostrar el funcionamiento correcto y eficiente de su lector frente al grupo.

En el reporte, los estudiantes fueron exigidos a analizar el estado del arte en el área de lectores de código de barras, presentar el diseño final y los resultados experimentales del funcionamiento de su lector, e interpretar dichos resultados.

6 Formato de Desarrollo del Proyecto

Probamos diferentes formatos de desarrollo de los proyectos: desde 8 hasta 16 semanas, paralelo y secuencial a las clases teóricas y laboratorio. De acuerdo con la opinión de los profesores y estudiantes, el mejor formato fue de 12 semanas de duración, paralelo a la materia teórica y a las respectivas sesiones del laboratorio, empezando una semana después del comienzo del semestre y finalizó tres semanas antes del término de éste. De este modo, no interfirió con varias actividades de los estudiantes al inicio del semestre y no obstaculizó la preparación de estudiantes para sus exámenes finales.

7 Evaluación

Para evaluar la eficacia de los Proyectos en la obtención de su objetivo y metas educativas, aplicamos encuestas a los estudiantes y profesores que imparten la asignatura, analizamos informes de los estudiantes sobre el desarrollo de sus respectivos proyectos, así como comentarios y observaciones de los alumnos y profesores en las presentaciones de los resultados parciales y finales de los proyectos.

Una encuesta anónima fue entregada a los estudiantes al inicio y otra al fin del proyecto. La encuesta proporcionada al inicio del proyecto estuvo centrada en una estimación de su preparación académica para desarrollar el proyecto, además había preguntas sobre los planes profesionales para el futuro y aspiraciones por desarrollar una carrera profesional exitosa. La segunda encuesta anónima a los estudiantes estuvo enfocada en su percepción de las características de los proyectos, dificultades encontradas por los estudiantes durante el desarrollo del proyecto, sobre las debilidades y fortalezas en la preparación académica de los estudiantes, y su estimación de impacto y utilidad académica de desarrollo del proyecto. Además, repetimos las preguntas sobre los planes para el futuro y aspiraciones para desarrollar una carrera profesional exitosa.

Los informes, el dispositivo lector de código de barras desarrollado, y la calidad de las presentaciones frente al grupo fueron evaluados por un comité conformado por al menos dos profesores que impartieron el curso teórico y dirigieron el laboratorio correspondiente (Los detalles de la estrategia de investigación y metodología empleada: las variables de investigación, los criterios, indicadores y escalas de medición, diseño de cuestionarios, el desarrollo y evaluación de la experiencia evaluación, y los resultados en forma amplia serán presentados en publicaciones futuras).

8 Resultados Técnicos del Proyecto

En primera instancia, los equipos estudiaron el estado del arte y prototipos de lectores de códigos de barras existentes. Después, cada equipo desarrolló su propio modelo de lector de código de barras (Figura 3). En cada fase del desarrollo del proyecto los estudiantes se enfrentaron con problemas técnicos que los incitaron a un autoaprendizaje. De igual forma, se presentaron muchos errores en la toma de decisiones. Evidentemente, ellos buscaban la solución más simple cuyas desventajas y limitaciones fuesen mínimas. Por ejemplo, casi todos los equipos intentaron implementar un lector de código de barras pasivo: dispositivo basado en la iluminación existente del ambiente para la detección óptica de las barras del código. Esto produjo una baja calidad de la señal en comparación con la de un dispositivo activo, el cual posee una fuente interna de luz modulada y emplea el filtrado óptico para eliminar la iluminación del fondo.

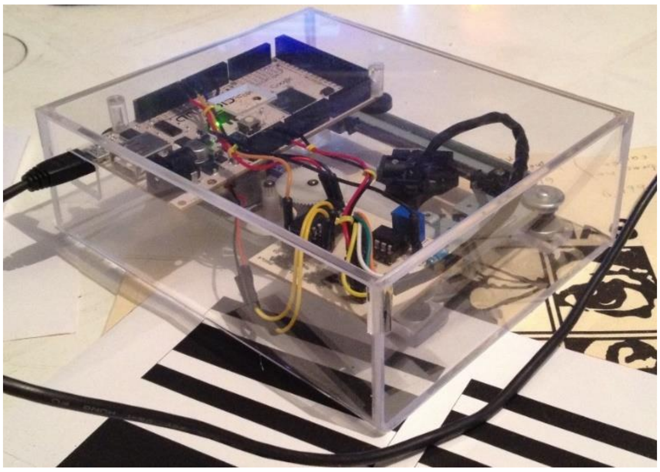

Figura 3: Una variante del lector de código de barras desarrollado por un equipo de trabajo

Dificultades similares se presentaron en el diseño e implementación de los subsistemas del lector de código de barras. La conversión de una señal analógica pobre en un código digital representó otro gran problema. Muchos de los equipos utilizaron convertidores analógico-digitales y procesaron la señal digital en una computadora. Sin embargo, lograr un porcentaje de error relativamente en la conversión analógica-digital se convirtió en una de las tareas más difíciles durante el desarrollo del proyecto.

Varios equipos decidieron emplear un microprocesador en el lector de código de barras. A pesar de que los microprocesadores no son abarcados dentro del plan de estudios, los estudiantes aprendieron de manera independiente a cerca de su uso y los aplicaron en el diseño de su lector de código de barras. Esto permitió un adecuado procesamiento de señales analógicas pobres, con un bajo porcentaje de error.

Otros problemas estuvieron ligados al tiempo establecido para el desarrollo de este proyecto. Debido al tiempo relativamente corto, algunos equipos solo lograron desarrollar la parte analógica del lector de código de barras.

9 El Resultado Educativo

Las encuestas a los estudiantes y profesores demostraron que los estudiantes aceptaron el proyecto con entusiasmo. Cada equipo estaba ávido por desarrollar su propia versión del lector de código de barras. Al término del proyecto, una parte representativa de los estudiantes lo consideraron el elemento más educativo de los planes de estudio. Ellos aceptaron que su participación dentro del proyecto reveló muchas deficiencias en su conocimiento. Su reacción ante este déficit fue positiva, estimuló el autoaprendizaje y el trabajo en equipo. Los conocimientos adquiridos también fueron muy buenos. Esto abarca tanto las habilidades profesionales de ingeniería como sociales y de comunicación.

Por otro lado, observamos que la tarea era demasiado compleja para algunos equipos menos preparados y menos eficientes, para ser completada a tiempo sin un esfuerzo extra. Por consiguiente, opinamos que sería académicamente más eficaz implementar el proyecto en dos semestres consecutivos, con el diseño teórico y la aplicación práctica distribuida en los dos semestres. Sin embrago, esta opción es poco práctica en nuestras condiciones actuales. Se espera que con una mejor preparación de estudiantes por medio de prácticas virtuales y reales, de distintas asignaturas de Ingeniería en Telecomunicaciones, sea más práctico y totalmente factible implementar el AOP en forma de una materia de varios Módulos de Salida de la carrera.

Comparando los resultados de semestres en los cuales se les asignó a los estudiantes un proyecto teórico y un práctico se observó que las calificaciones de los estudiantes mejoraron debido al proyecto práctico un porcentaje mayor de estudiantes entrego el proyecto práctico que el teórico a pesar de que el práctico requería mayor inversión en tiempo y esfuerzo.

10 Conclusiones

El desarrollo de proyectos prácticos sobre algunos temas de ingeniería por los estudiantes de últimos semestres es un recurso disponible y eficaz para habilitar los estudiantes en la solución de los problemas prácticos de ingeniería, para que ellos sean capaces de cumplir con un resultado específico de ingeniería. Con una selección inteligente de los temas de proyectos, estos favorecen a la integración del conocimiento aprendido en varios cursos, habilitan el auto-aprendizaje de los estudiantes y su capacidad de trabajar eficientemente en equipos y compartir responsabilidades del proyecto. Con base en nuestra experiencia, sugerimos a la academia tanto la introducción más amplia de las prácticas virtuales y reales, así como el AOP en forma de los Proyectos de los Módulos de salida de la carrera, en forma de una materia.

11 Agradecimientos

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Tutors work design to support a *curriculum* based on projects

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Abstract

The change of a traditional curriculum into another based in projects claims the inclusion of a new character in the process, the Tutor. The tutor's role, as discussed in this work, was designed as a student advisor to accompany them throughout the 1st grade of the engineering course in two different dimensions: as a mentor of students, being an example of professional and, as a coach of the students, in order to help them identify their skills and improve them. Moreover, the Tutor should support the freshmen on choosing activities that must be carried out along the 1st year, guiding them in studies and following them in an open way, listening to their complaints and trying to identify difficulties that may result in low performance and even evasion of course. At the curricular reform implementation, the Tutor should be the regulator and help to lead the change by doing the diagnosis of strengths and weaknesses, threats and opportunities, ensuring the possibility of progress and route correction, being always attentive to students and seeking for the success of the reform. That is a big challenge since the 1st grade has more than 1,000 students. In order to construct this new character, some steps had already been fulfilled and others had been planned. At the meetings, the team leader presented a brief summary of the main ideas and some questions that had to be answered by team. After that, the leader proposed some themes, which were discussed in small groups and the results of these discussions were presented in a plenary, allowing identify consensus. The results showed that tutor need to know the curriculum, projects, the subjects of 1st year course, and all the institutional means of assistance to the student, in order to give them directions and advise them successfully.

Keywords: Project-based learning; Tutoring; Mentoring; Coaching.

O Projeto do trabalho do tutor como suporte de um currículo baseado em Projetos

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Resumo

A mudança de um currículo tradicional para um outro baseado em projetos necessita a inclusão de um novo personagem no processo, o Tutor. O papel do tutor, como discutido neste trabalho, foi concebido como um orientador de alunos para acompanhá-los ao longo do 1º ano do curso de engenharia em duas dimensões: como mentor de estudantes, sendo um exemplo de profissional e, como treinador de estudantes, a fim de ajudá-los a identificar suas habilidades e melhorá-las. Além disso, o tutor deve apoiar os calouros sobre a escolha de atividades que devem realizar ao longo do primeiro ano, orientando-os nos estudos e, ainda, acompanhá-los de uma forma aberta, ouvindo suas queixas e tentar identificar as dificuldades que podem resultar em baixo desempenho e até mesmo evasão de curso. Na implementação da reforma curricular, o Tutor deve ser o regulador e ajudar a liderar a mudança, fazendo o diagnóstico de pontos fortes e fracos, ameaças e oportunidades, assegurando a possibilidade de progresso e correção de rota, estando sempre atentos a estudantes e buscando o sucesso da reforma. Isso é um grande desafio desde a primeira série com mais de 1.000 alunos. Para construir esse novo personagem, alguns passos já foram cumpridos além de outros planejados. Nas reuniões, o líder da equipe apresentou um breve resumo das principais ideias e algumas questões que precisavam ser respondidas pela equipe. Depois disso, o líder propôs alguns temas que foram discutidos em pequenos grupos e os resultados dessas discussões foram apresentados em uma sessão plenária, permitindo identificar consenso. Os resultados mostraram que tutor precisa conhecer o currículo, projetos, os temas de primeiro ano de curso, e todos os meios institucionais de assistência ao aluno, a fim de dar-lhes instruções e aconselhá-los com sucesso.

Keywords: Project-based learning; Tutor; Mentor; Treinador.

1 Introdução

É sabido que a evasão de alunos nos primeiros anos dos cursos de engenharia é um fenômeno que ocorre em nível mundial (Kolmos & De Graaff, 2007). Tal fenômeno está associado a incontáveis fatores, dentre os quais, certamente, pode-se relacionar a carência de fundamentos de matemática e física, a desmotivação devido aos currículos tradicionais com elevada cargas horárias centrados em aulas expositivas e na figura do professor que expõe o conteúdo na lousa, e, algumas vezes, a falta de vocação do aluno e a inexistência de elementos que possam despertar essa vocação pela engenharia nas primeiras séries.

Em agosto de 2013 a Reitoria do Centro Universitário do Instituto Mauá de Tecnologia – CEUN-IMT propôs aos coordenadores dos cursos de engenharia uma mudança de paradigma educacional nos cursos oferecidos pelo Instituto. O desafio da proposta e deste novo paradigma foi prontamente aceito pelos coordenadores e iniciou-se o planejamento de um modelo de ensino próprio, que começou a ser implantada junto aos alunos ingressantes na 1ª série de 2015. Os principais focos da mudança foram: a adoção de um modelo educacional com base em projetos eletivos e com grande variedade de temas, desenvolvidos pelos alunos desde a primeira série (mais de 40 atividades eletivas distintas, oferecidas aos ingressantes); a mudança metodológica das disciplinas tradicionais com o deslocamento do foco de atenção, do professor, para o aluno; o uso contundente dos recursos tecnológicos disponíveis para o ensino tais como os ambientes virtuais de aprendizagem (Moodle), utilizados como forma de apoio às aulas presenciais; vídeo aulas e uso de recursos multimídia em sala de aula.

O oferecimento de atividade eletivas (projetos e oficinas) aos ingressantes na 1ª série dos cursos de Engenharia em 2015, pretende envolver esse estudante no contexto de seu curso, gerando motivação e interesse pelos diferentes aspectos da Engenharia desde a primeira série. Desta forma é possível a personalização de cerca de 20% da grade curricular da 1ª série por meio das escolhas dos projetos e oficinas eletivas, conforme o interesse e o direcionamento desejado pelo aluno. Neste contexto de uma inesperada liberdade de escolha, e, de forma a oferecer ao estudante uma orientação especializada, bem como acompanhar e orientar a sua vida acadêmica na primeira série do curso de engenharia, foi criada a figura do tutor de turma.

O tutor foi pensado como sendo o elemento regulador da reforma curricular, orientando e procurando conduzir o aluno a extrair o melhor de si, bem como ser um fornecedor de informações provenientes do estudante para a coordenação do ciclo básico dos cursos de engenharia. Além disso, dada a ampla experiência dos profissionais convidados a participar deste programa, deverá atuar também como um mentor, no sentido de ser exemplo, destacando aos estudantes sua experiência no ensino, na pesquisa e na atuação profissional fora da academia.

O objetivo deste trabalho é apresentar a fase inicial de implantação do trabalho de tutoria que, no caso relatado, apresenta particularidades que fazem do tutor tanto um *coaching* como um *mentoring*, colaborando para a formação e o processo de decisão dos estudantes.

Cabe lembrar Kolmos e De Graaff (2007), que indicam que a implantação de estratégias ativas é mais difícil em escolas que têm um histórico de ensino tradicional quando passam a trabalhar com estratégias centradas nos estudantes. Daí a importância de realizar um trabalho de acompanhamento do estudante, sem o que a chance de percalços ao longo do processo de implantação pode comprometer o trabalho realizado.

2 Fundamentos teóricos

O mundo atual tem solicitado engenheiros com competências que vão além do saber técnico da sua profissão (Engineer2020, 2004). Habilidades como liderança, saber trabalhar em equipe, saber comunicar-se, dentre outras (Passow, 2012; Mason, Williams e Cranmer, 2009; Lima, Mesquita e Rocha, 2013), são competências que exigem prática e uma mudança de atitude para serem atingidas. Essa mudança no padrão de comportamento do estudante, não são alcançadas somente com o trabalho docente, havendo a necessidade de se ter uma apoio ao estudante, que o estimule a mudar, a ter um comportamento diferente do que viveu na etapa pré-universitária.

Cabe ainda considerar que na visão de Pacheco (2005), o currículo é a estrutura operacional que dá suporte à formação do estudante, desde o ingresso até a saída do processo de ensino aprendizagem. Nessa perspectiva, o currículo prevê o conjunto de elementos que definem objetivos, instrumentos de avaliação, estratégias de ensino. Considerando todas as dimensões do currículo, pode-se incluir como mais um elemento a estrutura de suporte ao estudante que, no caso de uma reforma curricular que questiona o paradigma vigente, tem peso suficiente para dificultar que ela avance da forma planejada.

Pacheco (2005) indica diversas etapas na criação de um currículo, partindo do currículo *ideal*, seguido pelo currículo *formal*, que se revela nos manuais e livros de texto e que traduzem o *ideal*. O nível seguinte é o currículo *operacional*, formatado em grupo e planificado individualmente, "*é o que acontece na prática diária e que se compara ao currículo ideal*". É nesse nível de currículo que se encontra o trabalho aqui relatado.

Dentre outras necessidades, Powell e Weenk (2003) indicam três condições para o sucesso em mudanças curriculares que caminham no sentido do PBL: Infraestrutura – física, de comunicação e de treinamento de pessoas. Autoridade – que garanta o planejamento guiado e, consequentemente, uma implementação aceita e institucionalizada, com compartilhamento de compromissos e visão sobre a estratégia de aprendizagem. Consenso - entre os participantes diretos sobre os objetivos do processo de inovação.

Existem na literatura diferentes significados para a forma de atuação de um tutor. Dentre estes pode-se citar:

- Tutor como facilitador/mediador nas abordagens PBL;
- O tutor como *coaching/mentoring* (Bettinger & Baker, 2011), prática corrente no mundo corporativo, com importantes reflexos no ensino superior, quase sempre na linha do treinamento de habilidades profissionais específicas e no planejamento da carreira;
- O tutor na abordagem de *peer tutoring* (Topping, 1996).

Os conceitos de *coaching* e *mentoring* quando aplicados ao ensino quase sempre se confundem (Bettinger & Baker, 2011). São claros, contudo, quando utilizados no mundo empresarial, sendo o coach o tutor que conduz o *tutee* a atingir objetivos específicos, enquanto o *mentor* orienta e aconselha os seus *tutees* utilizando sua grande experiência profissional com o aconselhamento e exemplo.

Com elementos do *coaching* e do *mentoring* foi elaborado o programa de tutoria aqui abordado, onde tutor é concebido como um professor com apreciável experiência profissional na docência, que nesse caso caracterizaria a tutoria como uma forma de *coaching*, e também fora da docência, preferencialmente no exercício da engenharia, o que permite caracterizar esta forma de tutoria como um tipo de *mentoring*.

3 Metodologia

3.1 Contextualização do campo de pesquisa

O universo de aplicação do programa de tutoria é de cerca de 1100 alunos ingressante no curso de engenharia, sendo 850 do curso diurno e 250 do curso noturno. Na 1ª série os estudantes não são, ainda, separados nos diferentes cursos de engenharia, mas participam de um ciclo básico de disciplinas de formação, comum a todos as áreas. Some-se a isso, como ponto central da reforma curricular, o oferecimento dos 40 projetos e oficinas aos ingressantes na 1ª série em 2015. Neste contexto a figura do tutor de estudantes foi pensado como sendo o elemento orientador do corpo discente e, ao mesmo tempo, regulador da reforma curricular, que por meio de um constante contato com o corpo discente forneceria à coordenação do curso o necessário feedback para rápidas correções de rumo. Contudo, o modelo de tutor, seu papel junto ao corpo discente e à instituição, foi de fato elaborado e consolidado a partir de encontros com os professores escolhidos pela coordenação do ciclo básico, como potenciais Tutores.

3.2 A estrutura da pesquisa

A pesquisa pode ser enquadrada na categoria de um estudo de caso exploratório. Partindo de uma pré-concepção sobre o papel do tutor, a coordenação do curso convidou um grupo de docentes selecionados para a discussão, construção e consolidação do papel do tutor. O trabalho com o grupo de docentes foi conduzido na forma de um *focus-group*, com questões que direcionaram as discussões e cujo objetivo foi de identificar como o grupo percebia: o perfil do tutor, as necessidades para a ação nesta função, bem como as necessidades de infraestrutura para a realização desse trabalho. Além disso, a reunião permitiu identificar potenciais líderes para a condução desse processo. As dimensões para a discussão foram trazidas pela coordenação, mas as categorias de análise surgiram após a coleta e análise dos dados.

Na reunião de discussão os professores convidados foram divididos em equipes nas quais as questões foram discutidas, gerando um relatório da equipe. Esses relatórios foram a base de dados para a construção das categorias de análise. O método da análise do conteúdo documental (Lüdke and André, 1986), serviu como referência para a análise dos dados.

Após essa reunião, aconteceram encontros entre os membros de uma equipe que assumiu a gestão do processo, liderada pelo responsável pela implantação da tutoria. Nessas reuniões, realizou-se a formalização da proposta e deu-se o início da elaboração de manuais e roteiros para o trabalho do tutor junto aos estudantes. Os documentos gerados nessas reuniões compõem uma segunda fonte de dados, uma vez que eles passaram a constituir o material do currículo operacional.

Uma segunda reunião com o grupo de tutores foi realizada com o objetivo de compartilhar o material produzido nas reuniões da equipe gestora. Nessa etapa, o currículo operacional foi apresentado aos professores, e sobre ele foram iniciadas as atividades da tutoria.

4 Resultados

A partir das reuniões surgiram três dimensões que são discriminadas e analisadas a seguir.

4.1 Perfil do tutor

Na primeira reunião, foram formados subgrupos, nos quais os professores discutiram e indicaram alguns elementos importantes para o trabalho de tutoria, muitos dos quais apareceram na maioria das equipes, a saber:

- O conhecimento da Instituição, em particular a sua infraestrutura de apoio ao aluno em todos os níveis;
- Saber ouvir;
- Ser acessível e sensível;
- Ser paciente e acolhedor;
- Criar vínculo com o aluno;
- Ser conhecido e conhecer os alunos
- Estar atento a identificar, no corpo discente e na estrutura da Instituição, problemas de toda sorte;

Outras contribuições, que apareceram em um ou outro grupo de discussão, também acrescentaram elementos para a consolidação do perfil e papel do Tutor, tais como:

- Incentivar o aluno para que ele comece a ser mais produtivo, aprendendo a buscar soluções;
- A tutoria deve buscar mudança de paradigma na transição do ensino médio para o superior;
- Liderança;
- Perseverança.

Pode-se ilustrar a discussão com alguns excertos das falas dos professores participantes do *focus-group*: *"...ser conhecedor da carreira da engenharia."; "...estar atento a identificar problemas e orientar."; "...ter bom relacionamento."; "O tutor deve acompanhar o aluno, ele é quem deve buscar, constantemente, o aluno."*

É interessante notar que muitos desses elementos, ou habilidades que os professores valorizam para poderem atuar junto aos estudantes, são justamente aquelas que devem ser desenvolvidas nos estudantes, identificadas como habilidades transversais (Lima, Mesquita e Rocha, 2013).

4.2 Necessidades para realização do trabalho do tutor

Os subsídios recolhidos na primeira reunião com os potenciais tutores, indicaram as necessidades, na visão do professor, para o trabalho do tutor com sua turma. São a seguir relacionadas:

- Horário regular de tutoria, inserido na grade horária do estudante;
- Controle de presença;
- Sistema de registro (prontuário do aluno);
- Programa de treinamento para os tutores;
- Ambientes apropriados para o trabalho em equipes e atendimento individual;
- Sistema de TI para acompanhamento do aluno.

Tais necessidades não surpreendem, coincidindo com aquelas que se espera para esse tipo de atividade Elas fazem parte do que indicado por Powell e Weenk (2003), relativamente à 'infraestrutura', o que parece ser o primeiro nível a ser atendido no início de um novo trabalho. Alguns excertos das falas dos participantes ilustram o tema: *"...sala apropriada para reuniões."; "...ambiente para atendimento individual"; "Treinamento para os tutores."; "Sala com ambiente propício, mesa redonda."; "Computador (Sistema de acompanhamento)."*

4.3 Número máximo de alunos para o trabalho com o tutor

Dada a dimensão do corpo discente que o Centro Universitário atende em seus cursos de engenharia a relação número de estudante por tutor, se apresentava como o grande desafio a ser vencido para o sucesso do programa. Com essa limitação em mente, a resposta do grupo de potenciais tutores para essa questão oscilou de 20 a 40 estudantes por tutor.

4.4 A proposta implementada

A segunda reunião, com base na primeira, deu início ao trabalho de tutoria formando um grupo gestor do programa que criou a estrutura da tutoria. Nesta fase, considerou-se também o levantamento de dados a partir do concurso vestibular para ingresso ao curso, de forma a gerar um diagnóstico inicial do estudante com base em seu desempenho em matemática, ciências físicas e redação. Tal possibilidade permite a personalização das necessidades dos alunos e das orientações do tutor, que dispõem de relatórios personalizados que são disponibilizados ao tutor do estudante. A partir destes dados, e após o diálogo com o aluno, o tutor faz a inscrição deste nos projetos e oficinas disponíveis e desejadas pelo estudante. Respeita-se assim a vontade e motivação do estudante, e a orientação especializada do tutor, embasada em dados de um diagnóstico personalizados de cada aluno. Durante o ano letivo, o tutor acompanhará o desempenho do aluno em suas atividades de projetos e oficinas eletivas, e também nas disciplinas tradicionais, por meio de um sistema de TI desenvolvido para esta finalidade.

O programa de tutoria será desenvolvido junto aos alunos ingressantes no curso de Engenharia, em encontros semanais com turmas de até 30 estudantes, durante todo primeiro ano do curso. Embora com algum atraso na capacitação/treinamento do grupo de tutores, foi possível atingir uma relação de cerca de 30 estudantes por tutor, número este intermediário àqueles que haviam sido sugeridos pelo trabalho inicial como os professores.

A tutoria desenvolve ao longo do ano atividades na forma de dinâmicas de grupo, com foco no desenvolvimento da integração entre os estudantes, no trabalho em equipe, nas formas de comunicação, no desenvolvimento de lideranças e na contextualização socioeconômica do país, abordando e desenvolvendo, também, diversos temas transversais indicados nas diretrizes curriculares nacionais do Brasil para os cursos de Engenharia. O Tutor oferece a orientação especializada aos alunos quanto a suas escolhas e condução das atividades oferecidas (projetos e oficinas), e, além disso, faz também, quando necessário, o encaminhamento do estudante aos diversos programas institucionais de apoio às disciplinas, monitorias, acessibilidade e psicopedagógicos. Nesse sentido o programa de tutoria cria um diferencial no ensino superior de Engenharia no Brasil.

5 Considerações finais

O objetivo deste trabalho é apresentar a fase inicial de implantação do trabalho de tutoria no Centro Universitário do Instituto Mauá de Tecnologia, uma tradicional Instituição de ensino superior, com foco nos cursos de graduação em engenharia, administração e design. A Instituição fez a opção por uma mudança de paradigma em seu processo de ensino. Na implementação da mudança em 2015, a nova proposta de ensino mantém as disciplinas tradicionais, contudo com importantes mudanças metodológicas centrando a atenção no trabalho do aluno e menos na atividade expositiva do professor. Além disso, 20 % da carga horária foi destinada a atividades eletivas, projetos e oficinas, já desde a 1ª série, o que insere uma nova responsabilidade ao estudante: a construção e personalização de seu currículo.

A coordenação do curso e seus professores elencaram um novo elemento no processo de mudança curricular, o tutor de turma. O tutor, elemento concebido como um professor experiente e, preferencialmente, com atuação na docência e na prática da engenharia, tem o papel de interlocutor do estudante com a instituição, e, também, uma atuação fundamental para o sucesso da reforma curricular desempenhando ações de *coaching* e *mentoring* junto aos alunos da 1ª série. As indicações sobre as funções, características pessoais e necessidades para a execução do papel de tutor, foram obtidas nas reuniões com o corpo docente. Tais indicações têm sido implementadas e somam-se a outras ações desenhadas e executadas por um grupo gestor do programa de tutoria. Assim, várias ações, tais como: o uso de dados dos exames vestibulares como forma de diagnóstico e personalização do trabalho do tutor junto ao aluno; a geração de um prontuário de acompanhamento do estudante; um sistema de registro e controle das atividades dos alunos em seus projetos e disciplinas regulares, além de um planejamento de atividades na forma de dinâmicas de grupo, constituem a estrutura de trabalho do programa de tutoria. Tem por finalidade, envolver e motivar o aluno em seu curso, evitar a evasão e despertar vocações para a engenharia, auxiliar a personalização da grade curricular do aluno, e, monitorar e corrigir os caminhos da implantação da reforma curricular.

Os resultados da implantação deste programa de tutores em 2015 orientarão os caminhos da Instituição no sentido da condução e orientação de formas mais contundentes da aprendizagem ativa, que irão dispor de um mecanismos capaz de fornecer rápido *feed-back*. Além disso, a ação dos tutores deverá substituir parte das funções das coordenações dos cursos de engenharia, atendendo as demandas dos estudantes de forma menos impessoal do que ocorre atualmente decorrente do grande universo de alunos.

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Engine Study with High School Students using PBL Methodology

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Abstract

The development cycle in Brazil is generating a strong need for engineers. However, the number of available professionals in this area isn't covering the demand. To mitigate this situation some actions were proposed by both the government and the universities. One ongoing project that was started in 2010 by the Joinville campus of the Federal University of Santa Catarina (UFSC) is delivering specific actions among the high school youth of the city in order to encourage further study in engineering. One of the studies developed with the project based learning was the analysis of engines cycle. Here, high school students reviewed the functions and parts of combustion engines with the aid of academic undergraduates and teachers. Such analysis started with the explanation of the project, followed by a literature review. By the end the high school students were able to understand and identify the components of an engine, showing strong interest in the engineering field.

Keywords: high school students; project based learning; engines.

Estudo de Motores a Combustão com Jovens Estudantes do Ensino Médio Utilizando PBL

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Resumo

O ciclo de desenvolvimento no Brasil gerou uma forte demanda de engenheiros. No entanto, o número de profissionais disponíveis nesta área não é suficiente. Para atenuar esta situação algumas ações foram propostas tanto pelo governo como por algumas universidades. A UFSC/Joinville iniciou em 2010, alguns projetos com os jovens do ensino médio na cidade, a fim de incentivar o estudo em engenharia. Um dos projetos desenvolvidos é com o uso da aprendizagem baseada em projetos, com o tema de análise do ciclo de motores. Neste projeto, os alunos do ensino médio realizam a avaliação das funções e partes de motores de combustão com a ajuda de estudantes de graduação e professores. O projeto se inicia com a explicação dos conceitos básicos de motores, seguido de atividades de pesquisa e de laboratório. Ao final os estudantes do ensino médio foram capazes de compreender e identificar os componentes de um motor, mostrando forte interesse na área de engenharia.

Palavras-chave: estudantes do ensino médio, aprendizagem baseada projeto; motores.

1 Introdução

Uma pesquisa realizada pelo Programa Internacional de Avaliação aos Alunos - PISA, que compara o desempenho escolar dos países para alunos de 15 anos revelou que o Brasil, em 2012, estava na 58ª posição no ranking que relaciona a matemática, na 59ª posição em ciências e na 55ª posição em leitura (entre 65 países). (Inep, 2013)

Essa questão coloca o Brasil em ritmo de crescimento diferente dos países desenvolvidos, quando se fala em avanço tecnológico e vantagem competitiva no mercado, pois não é possível ser classificado como país desenvolvido se não existe uma base forte em ciência e tecnologia formando os futuros profissionais deste setor.

Pesquisas demonstram que nos últimos anos, seis países se destacaram no cenário global, são eles: Cingapura, China, Japão, Canadá, Coréia do Sul e Austrália. A principal semelhança entre esses países está relacionada com a formação qualificada de profissionais ligados as áreas de engenharia, tecnologia da informação e principalmente com a criação de centros educacionais, que possam oferecer o retorno vantajoso e competitivo que a globalização exige.

No Brasil estudos apontam que haverá uma falta de mão de obra no campo de profissões relacionadas a tecnologia nos próximos anos. Um estudo realizado pelo Instituto de Pesquisa Econômica Aplicada (Ipea) demonstrou que, se a economia apresentar um crescimento médio de 3,5% ao ano, a quantidade de profissionais já formados não será suficiente para atender a demanda, principalmente por engenheiros nos próximos anos (Portella, 2010).

Cerca de 32 mil novos engenheiros são formados por ano no Brasil, o que é muito pouco quando comparado a outros países, como por exemplo, a China que forma em torno de 400 mil, ou a Índia, em torno de 300 mil. Segundo um estudo realizado pela CNI (Confederação Nacional da Indústria), o Brasil precisaria formar cerca de 60 mil engenheiros por ano para suprir a necessidade do mercado de acordo com Formiga (2011). Para piorar este quadro, algumas pesquisas indicam que vários estudantes brasileiros abandonam o curso de engenharia por não conseguirem acompanhá-lo, seja pela dificuldade inerente à formação ou por questões financeiras. Uma das possíveis razões para o baixo rendimento está ligada a pouca motivação que o ensino médio em relação a ciências, especialmente a física, química e matemática, matérias que são vetores de incentivo à carreira tecnológica (Calaza, 2009).

No intuito de contribuir para minimizar o déficit de engenheiros, os professores da UFSC/Joinville realizam atividades com estudantes de escolas públicas de ensino médio da cidade. Estas atividades têm como objetivo envolver estes estudantes em projetos, demonstrando alguns temas que o futuro profissional da área de engenharia irá atuar. Outro objetivo é incentivar a formação em universidades destes estudantes do ensino médio, principalmente em cursos da área de tecnologia. Para realizar este projeto foi utilizada a metodologia de ensino por projetos.

2 Ensino por Projetos

O ensino de modo geral e especialmente o de engenharia tem passado por uma série de reflexões, várias são as sugestões para a atualização e a realização de novas maneiras didáticas de se trabalhar em sala de aula, tendo o professor que utilizar uma ou várias técnicas de ensino, para buscar a motivação dos alunos.

Têm-se como técnicas de ensino presenciais, segundo Masetto (2003): aula expositiva, debate com toda a classe, estudo de caso, ensino com pesquisa, ensino por projetos, dramatização e dinâmicas de grupo.

Dentre as citadas anteriormente a de ensino por projetos é um método de educação sistematizado, tendo como principal objetivo aproximar o aluno o máximo possível de situações reais, colocando o estudante como membro ativo da aprendizagem (Rocha, 2003; Campos *et al*,2011).

Dentre as principais vantagens deste método podemos citar: vivência de situações reais, estímulo ao planejamento, proposição de uma ação organizada, compreensão da situação e do contexto, foco na atividade conduzindo o aluno para a realização de trabalhos de pesquisa e concretização, caráter integrador e desenvolvimento de pensamentos divergentes.

O método de ensino por projetos pode ser classificado como pertencente a teoria construtivista, que segundo Loyens *apud* Campos *et al* (2011) é baseado em:

- A aquisição do conhecimento é um processo de construção do conhecimento no qual o saber anterior representa o ponto de referência para as novas afirmações;

- O aprendizado envolve interação com os outros alunos e professores;

- A construção do conhecimento se beneficia de habilidades metacognitivas como planejar, monitorar e avaliar o processo de aprendizado;

- É importante que a aprendizagem se dê em um contexto autêntico, preferivelmente parecido com o futuro contexto profissional.

Segundo Campos et al (2011) alguns cursos de engenharia de universidades do mundo estão utilizando este novo método de ensino como na PUC-SP (Brasil), Twente e Eindhoven (Países Baixos), UMinho (Portugal), Aalborg (Dinamarca), Heilbronn (Alemanha) e Politecnica de Catalunya (Espanha). Nestes cursos os estudantes de engenharia relatam que obtiveram um maior nível de envolvimento nas atividades propostas, que o processo de aprendizado foi melhor e que a motivação foi maior, quando comparado ao ensino tradicional, que tem como base o professor no centro do processo de aprendizagem.

Na Universidade Federal de Santa Catarina – UFSC, campus de Joinville a metodologia de ensino baseada em projetos foi utilizada em um projeto que a universidade desenvolveu com estudantes do ensino médio de escolas públicas da cidade, que será descrito na sequencia.

3 Projeto

Para os estudantes e egressos do curso de engenharia mecânica ou automotiva, um componente veicular que exerce um grande fascínio é o motor de combustão (Figura 1), que é um sistema grandemente estudado e de pesquisas intensas para que a sua eficiência seja melhorada cada vez mais. O motor consiste em transformar energia térmica devido à queima de combustível em mecânica fazendo com que o veículo se desloque.

(a) (b)

Figura 1: Motor a combustão interna. (a) Pontiac G8 GT e (b) Motor Cadillac STS (INFOMOTOR, 2013)

O projeto que foi realizado propôs um estudo deste componente com o uso da metodologia PBL, sendo que os estudantes que participaram desta proposta são oriundos do ensino médio.

Um grupo de 6 estudantes foi selecionado para participar deste projeto, a seleção (baseada no histórico escolar e em entrevista) ocorreu entre alunos que participaram de atividades realizadas pela UFSC nas escolas de ensino médio. Estas atividades consistiam de oficinas e palestras.

Os estudantes selecionados foram incluídos no programa de iniciação científica para alunos do ensino médio (PIBIC-EM), recebendo uma bolsa mensal para custear o deslocamento entre a sua residência e a Universidade.

O local de realização do projeto foi no Laboratório de Inovação e Desenvolvimento de Produtos - LiD da UFSC/Joinville, assim os estudantes cursavam suas aulas normais pela manhã e a tarde, nos dias programados, realizavam as atividades previstas no projeto, sendo tutoriados por estudantes e professores do curso de engenharia automotiva.

As atividades do projeto foram estruturadas de acordo com a Tabela 1. Nos primeiros encontros foram apresentados aspectos básicos do projeto, o cronograma das atividades como também foram formadas as duplas de trabalho (neste caso 3 grupos de 2 componentes). Na sequencia, foram previstos encontros no laboratório, onde os grupos realizaram uma series de estudos, apresentando os resultados para os demais, estas apresentações foram acompanhadas por tutores, que complementavam as informações nos casos necessários.

Visando a realização de atividades práticas foi previsto neste projeto aulas de laboratório, com motores didáticos e reais, ao final desta atividade foi apresentado o trabalho de forma geral e realizado um relatório.

Tabela 1: Cronograma

Atividade	**Mês**					
	1	**2**	**3**	**4**	**5**	**6**
Conceitos iniciais	X					
Estudo em grupo		X	X			
Atividade em laboratório				X	X	
Apresentação geral					X	
Relatório						X

No primeiro mês foi realizado um encontro por semana, onde foram discutidos conceitos e origem do motor de combustão, bem como os ciclos mais utilizados em motores de combustão interna, onde podemos citar de acordo com UFPEL (2013) o ciclo **Otto** (mais comum em automóveis e motos), **Diesel** (mais usado em veículos pesados) e **Brayton** (utilizado em turbinas a gás).

O motor de combustão de quatro tempos (ciclo Otto), um dos mais utilizados, foi proposto pelo engenheiro francês Alphonse Beau de Rochas em 1862, sendo implementado pelo engenheiro alemão Nikolaus Otto August em 1872 (Brunetti, 2012).

Os automóveis atuais ainda usam o mesmo principio de funcionamento que o desenvolvido em 1872, neste ciclo, existem vários componentes como: pistão, biela, virabrequim, balancim, cabeçote, cárter, velas, mancal, comando de válvulas, entre outras, cada peça com uma determinada função.

A Figura 2 mostra alguns dos componentes do motor a ciclo Otto.

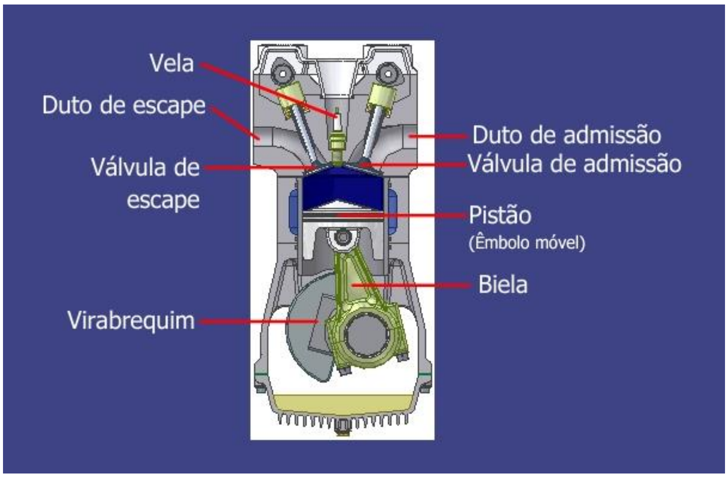

Figura 2: Motor ciclo Otto. (IF, 2015)

Após a apresentação dos conceitos iniciais, a fase de estudo em grupo seguiu com encontros semanais no laboratório, onde havia uma sequencia de pequenas apresentações dos grupos sobre assuntos que eram sugeridos pelos tutores, como por exemplo: Como o motor de combustão funciona? Qual a função de cada componente do motor? Quais as etapas do ciclo Otto? Quais os problemas que ocorrem e o que se pode ser realizado para aumentar a sua eficiência?

Caso fosse necessário os tutores complementavam as explicações dos grupos. Trabalhou-se nesta atividade o pensamento crítico dos grupos, sua capacidade de buscar informações nas mais variadas fontes, bem como o desenvolvimento pessoal nas apresentações.

Após a etapa de estudo, um kit didático de um motor com peças de plástico em tamanho reduzido foi disponibilizado a cada grupo, juntamente com as instruções de montagem. Esta atividade foi realizada no laboratório da UFSC com o auxílio de tutores.

Com o Kit finalizado, foi possível cada grupo visualizar o funcionamento do motor, como cada componente estudado na atividade anterior funciona e suas relações.

Posteriormente, a atividade de "*hands on*" ainda prosseguiu, com um pequeno motor de combustão, onde os grupos trabalhavam com tutores no laboratório da UFSC, em sua montagem, ajustes e análise de consumo, para que conseguissem relacionar o conhecimento construído até o momento. A análise de consumo foi realizada controlando a massa do combustível e tempo de uso do motor.

Ao final desta atividade, os grupos realizaram uma apresentação, onde foi avaliado o conhecimento e efetiva participação de cada estudante ao longo de todo o projeto. Uma avaliação por parte dos estudantes em relação as atividades propostas também foi realizada, para avaliar possíveis melhorias.

Posteriormente os grupos também participaram de um seminário de iniciação científica da universidade, voltada para os alunos de ensino médio, que pode ser observada na Figura 3 e 4.

Figura 3: Seminário de iniciação científica

Figura 4: Seminário de iniciação científica

4 Conclusão

Ao final deste trabalho, que utilizou o método de ensino por projetos (PBL) no estudo do ciclo do motor a combustão com um grupo de estudantes do ensino médio, foi possível verificar que este método de ensino se demonstrou uma prática viável que potencializou o interesse dos estudantes pelos assuntos abordados. Na literatura pesquisada o ensino por PBL é utilizado com frequência em universidades, com vários casos positivos relatados, contudo neste trabalho o PBL foi utilizado com estudantes de ensino médio, demonstrando que também é viável. O PBL é centrado no estudante, e o mesmo é motivado e orientado a buscar as informações necessárias para desenvolver o projeto.

Com a utilização deste método foi possível fazer com que o estudante contribuísse ativamente com o processo de construção do conhecimento, compreendesse a função técnica e a grande importância que o motor de combustão exerce em um veículo de transporte. Além disso, demonstrou como o engenheiro contribui para a melhora deste sistema técnico.

Durante o projeto os estudantes utilizaram técnicas de organização e trabalho em equipe (enfatizando o cumprimento de metas e prazos), praticaram ativamente o processo de exposição de ideias, melhorando aspectos de comunicação. O convívio e trabalho em grupo contribuíram para a construção do conhecimento, aproximando os estudantes à uma situação real de um futuro profissional de engenharia. Em suma, a vivência da situação real de utilização do PBL como técnica de ensino se mostrou extremamente adequada para os objetivos propostos de aprendizado.

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Encouraging the formation of future engineers through the active learning strategies

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Abstract

According to the 1988 Brazilian Constitution, the right to equality is ensured between genres and specific incentives of inclusion of women in thelabor market. Although the rights are guaranteed, are large disparities in Brazil, mainly in the North, in terms of equal pay, access to the labormarket, gender roles and professions historically taxed as men, among them are those involve engineering and exact sciences. Given these differences and the need for female skilled labor in the labor market the contraptions Laboratory Outreach Program developed the project "Stimulating Training Future Engineers", which was approved by CNPq (National Council for Scientific and Technological Development) aiming in the city of Ananindeua, located in the northern region of Brazil, the encouragement of public school students, to choose engineering and sciences courses, in addition to providing Junior Scientific Initiation scholarships for them. This municipality is in rapid economic development due to the encouragement of construction, making it essential the presence of skilled labor, the maxim female. In this way, this article presents the first results of this project. Which seeks to encourage the students of the school to follow the career of engineering, through training Introduction to Robotics by Arduino platform and LEGO kits, workshops of experiments which involve disciplines of chemistry, physics and mathematics and fairs scientific of sciences and engineering, making use of strategies for active learning, which combines theory with practice? In addition, the project has significant results, among them the admission of students in universities in the areas encouraged by the project and the improvement of efficiency in the disciplines of exact.

Keywords: Engineering; Active Learning; the Labor Market; Women in Engineering.

Incentivando a formação de futuras engenheiras mediante as estratégias de aprendizagem ativa

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Resumo

De acordo com a Constituição brasileira de 1988, o direito de isonomia é assegurado entre gêneros, bem como os incentivos específicos de inserção da mulher no mercado de trabalho. Ainda que os direitos sejam garantidos, são grandes as disparidades existentes no Brasil, e principalmente, na região Norte, em termos de remuneração equivalente, acesso ao mercado de trabalho, cargos entre gêneros e profissões taxadas historicamente como masculinas, dentre elas, as que envolvem engenharia e ciências exatas. Diante destas diferenças e a necessidade de mão de obra qualificada feminina no mercado de trabalho o Programa de Extensão Laboratório de Engenhocas elaborou o projeto "Estimulando a Formação de Futuras Engenheiras", visando no município de Ananindeua, localizado na Região Norte do Brasil, o incentivo de alunas de escolas públicas, a escolherem cursos de engenharia e ciências exatas, além de proporcionar bolsas de Iniciação Científica Júnior para as mesmas. Este município encontra-se em desenvolvimento econômico acelerado devido ao estímulo da construção civil e outros setores industriais, tornando-se imprescindível a presença de mão de obra qualificada, máxime a feminina. Desta maneira, o presente artigo apresenta os primeiros resultados deste projeto. O qual busca estimular as alunas do ensino médio a seguirem na carreira de engenharia, por intermédio de treinamentos de Introdução a Robótica pela plataforma Arduino e kits LEGO, oficinas de experimentos as quais envolvem disciplinas de química, física e matemática e participação de feiras científicas de ciências e engenharia, fazendo uso de estratégias de aprendizagem ativa, a qual alia a teoria à prática. Além disso, o projeto possui significativos resultados, entre eles o ingresso de alunas em Universidades nas áreas incentivadas pelo projeto e a melhoria de rendimento nas disciplinas de exatas.

Palavras-chave: Engenharia; Aprendizagem Ativa; Mercado de Trabalho; Mulheres na Engenharia.

1 Introdução

Durante muitos anos, a engenharia e ciências exatas tradicionalmente ditas como áreas masculinas, tornou-se um mercado atrativo para as mulheres, seja pelos cargos, salários ou posição social. Segundo um levantamento realizado pelo Instituto Brasileiro de Geografia e Estatística (IBGE,2012), observa-se que as mulheres não estão se atendo em obrigações domésticas, em contrapartida, estão buscando sua qualificação profissional, conquistando seus direitos e espaço no mercado de trabalho.

Tais direitos são conquistas do movimento feminista ocorrido nos Estados Unidos, durante as décadas de 60 a 90, mas que perduram até os dias atuais, com objetivo de alcançar a equidade e a libertação de padrões patriarcais preestabelecidos pela sociedade, bem como reforma nos planos de trabalho, conquistando uma igualdade individualista de homens e mulheres.

Muitos desafios ainda devem ser enfrentados na busca por maior igualdade no mercado de trabalho, tendo início a partir do ingresso equivalente das mulheres em cursos de engenharia e ciências exatas. Diante destas disparidades, bem como, o momento econômico favorável no setor da engenharia, percebe-se a necessidade de mão de obra feminina no mercado. Assim sendo, o município de Ananindeua localizado no estado do Pará, Região Norte do Brasil, é uma localidade a qual recebe grandes investimentos, em especial no setor imobiliário.

O Projeto ''Laboratório de Engenhocas: Estimulando a formação de futuras engenheiras'' aprovado pelo CNPq, vem sendo realizado no Brasil, precisamente no município de Ananindeua localizado no estado do Pará, distante cerca de 19 km de Belém (capital do estado). Situado na Região Metropolitana de Belém, é o segundo município mais populoso do estado e o terceiro da Região Amazônica, com a população estimada em 499.776 habitantes, segundo dados do (IBGE). O ramo de atividade mais dominante, dentre as indústrias do município de Ananindeua é o madeireiro, composto por treze empresas (representando 37% do total das empresas de

Ananindeua), acompanhado pelo de construção civil constituído por nove empresas e em terceiro o de móveis com quatro (SEDIC – 2005).

Para lidar com estes obstáculos, o programa "Laboratório de Engenhocas: Estimulando a Formação de Futuras Engenheiras", aprovado pelo CNPq incentiva por meio de bolsas de Iniciação Científica Júnior, usos de estratégias de aprendizagem ativa e monitoria com os discentes de engenharia e ciências exatas da Universidade Federal do Pará, as alunas da Escola Estadual de Ensino Fundamental e Médio Eneida de Moraes no município de Ananindeua, no estado do Pará. Sendo de suma importância, em razão de estimular o ingresso na Universidade, estreitar o contato com as alunas do ensino médio com a vida acadêmica, bem como, compartilhar e adquirir conhecimento entre os acadêmicos e os alunos da escola. Dessa forma, o modo de execução do programa é de demasiada importância para a comunidade escolar como um todo, tendo em vista a boa influência positiva que o mesmo vem proporcionando por meio de sua metodologia didática e interativa.

À vista disso, o presente artigo busca expor a proposta do Laboratório de Engenhocas, o qual promove a assimilação dos conteúdos do Ensino Médio por meio da aprendizagem ativa, buscando a participação do aluno em todo o processo de aprendizado, desde a teoria até as suas aplicabilidades no cotidiano, consolidando competências e habilidades interdisciplinares. As estratégias usadas para tal metodologia consistem na aplicabilidade de apresentações de experimentos, construções de jogos interativos com materiais de baixo custo, competições e participações em feiras de ciências, treinamentos de introdução à robótica com uso das plataformas Arduino e Kits LEGO, os quais envolvem além do conteúdo sobre a física, matemática e química, bem como o desenvolvimento da lógica e do lado lúdico possibilitando um aprendizado diferenciado.

2 A participação feminina no mercado de trabalho

Uma das primeiras publicações em periódicos científicos em uma das mais respeitosas revistas científicas, a *Science,* foi a de Alice Rossi (ROSSI, 1965), o qual discute a participação nos Estados Unidos de mulheres trabalhando em atividades de Ciência e Tecnologia, entre os anos de 1950 e 1960. Os dados obtidos demonstraram uma participação muito reduzida de mulheres empregadas em atividades de Ciência e Tecnologia em algumas áreas: elas representavam nas engenharias cerca de 1% do total de empregados; já nas ciências naturais a participação feminina foi de aproximadamente 10%, oscilando entre 5% na física e 27% na biologia. Diante do resultado, a autora abrangeu o papel de certos aspectos sociais e psicológicos os quais poderiam explicar a reduzida participação de mulheres na área de Ciência e Tecnologia nos Estados Unidos, são eles: a prioridade do casamento e da maternidade, a influência dos pais sobre a carreira a ser seguida pelos seus filhos, designando o que devem ser atitudes e comportamentos "femininos" e "masculinos" e incompatibilidades ou diferenças de cunho biológico e/ou social entre homens e mulheres, tal como nas habilidades cognitivas, na questão da independência, de persistência e do distanciamento do convívio social.

Um estudo realizado pela Unesco (MCGREGOR E HARDING, 1996) mostrou a crescente participação em instituições de educação superior nas décadas de 1970, 1980 e 1990 em países da América Latina, Europa Ocidental e Ásia. Tal crescimento demonstra um maior ingresso de mulheres na área de Ciência e Tecnologia. No Brasil, a expansão da comunidade científica e da ciência faz parte da história recente do país, pois até o século XX, o número de instituições voltadas para a ciência era muito limitado e foi no final dos anos de 1960, com a edição do Plano Estratégico de Desenvolvimento Nacional, que a questão científica e tecnológica surgiu como presença constante no planejamento nacional.

Após vinte e um anos de regime militar autoritário no Brasil, a Constituição de 1988 e, seu texto foi o marco da democracia brasileira o qual afirmou os direitos individuais e humanos dos brasileiros. Por mais que tais direitos sejam assegurados às mulheres, ainda são vistas na sociedade brasileira as grandes disparidades no que diz respeito, principalmente, ao acesso ao mercado de trabalho, remuneração e cargos entre gêneros. Este cenário é fruto de convenções sociais patriarcais as quais segregam o espaço e o ambiente de trabalho.

A certificação da autonomia social e econômica das mulheres é um dos eixos fundamentais e estruturantes das políticas que destinam à transformação das condições de vida e das desigualdades sociais, de gênero e raça experimentadas pelas mulheres, singularmente aquelas mais vulneráveis às discriminações decorrentes delas. No entanto, ao analisar dados relativos à participação das mulheres no mercado de trabalho, é possível perceber que há ainda, extensos desafios a serem enfrentados para o progresso da igualdade entre mulheres e homens.

Na população economicamente ativa (PEA) do Brasil, cerca de 42% das pessoas ocupadas são mulheres. Ainda que a taxa de desemprego das mulheres tenha caído de 15,2% para 7,5% entre 2003 e 2011, as mulheres ainda deparam-se com piores condições de trabalho, salários mais baixos e sofrem com o acúmulo de tarefas relacionadas à dupla jornada de trabalho, como também sofrem sistematicamente com a violência e a discriminação nas suas relações de trabalho, estando em número reduzido em determinadas profissões especialmente nas engenharias e áreas de exatas (PNDA, 2013). A jornada de trabalho é também uma das principais responsáveis pelas condições de trabalho desigual de mulheres e homens. Assemelhando mulheres e homens que trabalham fora, a Pesquisa Nacional por Amostra de Domicílios (PNAD, 2011) indica que a média de horas gastas em afazeres domésticos pelas mulheres é de cerca de 22 horas. Contudo, quando se trata dos homens o tempo médio gasto nestes afazeres é menos da metade: 10,3 horas em 2011. As desigualdades podem ser notadas da mesma forma com relação à remuneração. Mesmo sendo mais escolarizadas, as mulheres ganham menos.

3 Metodologia

Na tentativa de colaborar para a inserção de mais mulheres no mercado de trabalho, principalmente, em áreas onde ainda há muita presença masculina, o Programa de Extensão Laboratório de Engenhocas elaborou o projeto: “A Formação de Futuras Engenheiras” onde faz uso de estratégias de aprendizagem ativa, a partir de inovações metodológicas, abrangendo fatores interdisciplinares entre diversos conteúdos da ciência aplicada. Os métodos de aprendizagem ativa têm sido implementados para que haja uma eficiência melhor na forma de aprendizado, pois, diferente das aulas tradicionais, nas quais os alunos são receptores passivos de todo o conteúdo exposto em sala de aula, a metodologia aplicada na aprendizagem ativa busca por meio de estratégias pedagógicas inovadoras, uma postura mais ativa por parte dos alunos.

Essas estratégias fazem uso de desenvolvimento de projetos, lançamento de desafios, assim como problemas-discussão, a fim de obter uma dedicação maior por parte dos alunos, bem como uma notória eficácia na sua proatividade, não os deixando limitados apenas no conteúdo exposto em sala de aula, mas, incentivando-os a buscar conteúdos complementares em outras diversas fontes disponíveis, como forma de agregar mais informações e aperfeiçoar a construção de seus conhecimentos. A partir desse pressuposto, os docentes e discentes do Programa de Extensão Laboratório de Engenhocas vêm trabalhando essa metodologia de forma direta na E.E.F.M.Eneida de Moraes em alunas da rede estadual de ensino, visando no futuro à incorporação de mais mulheres engenheiras no mercado de trabalho paraense.

Para alcançar o objetivo proposto, iniciou-se na E.E.F.M.Eneida de Moraes a realização de oficinas de experimentos os quais envolvem as disciplinas de física, química e matemática, somente para o público feminino. Nestas oficinas, as habilidades e competências interdisciplinares foram colocadas em prática, uma vez que foi necessário o uso do conhecimento de ambas as disciplinas, além da necessidade de haver estudos, pesquisas e interações, resultando em trocas de ideias, para assim, constituir a aquisição de novos conhecimentos, mediante a interação conjunta do meio, do recurso e das alunas que estavam presentes. As oficinas tiveram como tutores as discentes da Universidade Federal do Pará e participantes do Programa de Extensão Laboratório de Engenhocas, como demonstrado na Figura 1.

Figura 1: Oficinas de experimentos de física química e matemática na E.E.F.M.Eneida de Moraes

Posteriormente, o Programa de Extensão Laboratório de Engenhocas desenvolveu na Escola Estadual do município de Ananindeua Eneida de Moraes treinamentos de Introdução à Robótica com a Plataforma Arduino. O treinamento com a plataforma Arduino básico consistiu em apresentar as alunas desse recinto escolar, noções básicas de programação, robótica e eletrônica, alguns atrelados aos conceitos físicos do ensino médio. Como meio de apresentar a proposta de aprendizagem ativa, os integrantes do Laboratório de Engenhocas pediram as alunas para que as mesmas relatassem o conteúdo ministrado semanalmente, e apresentassem um projeto. As alunas ressaltaram a importância das pesquisas e estudos realizados no período da didática aplicada, e afirmaram possuir uma melhor absorção do conteúdo exposto após serem apresentadas a esta nova metodologia de ensino, na qual foi baseada no compartilhamento de informações, troca de experiências e ideias. Logo a Plataforma Arduino, torna-se um método efetivo para estreitar laços com o mercado de trabalho, mediante a linguagem de programação, uma ferramenta imprescindível na atual composição da engenharia.

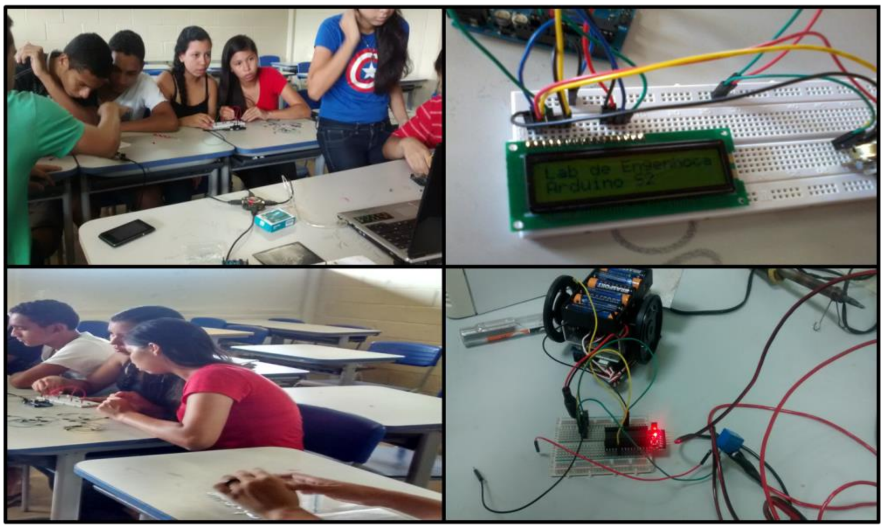

Figura 2: Treinamentos de Introdução à Robótica na Escola Estadual Eneida de Moraes.

O projeto ''Estimulando a Formação de Futuras Engenheiras'' desenvolveu na E.E.F.M.Eneida de Moraes oficinas para criação de jogos interativos com uso de materiais alternativos e/ou de baixo custo (MILHOMEM, *et al.*, 2013), a fim de aproveitar materiais recicláveis para a fabricação de jogos que incitem o raciocínio lógico das alunas, como também, expandir a responsabilidade e conscientização socioambiental das mesmas. Em razão disso, acredita-se que um dos atributos marcantes dos jogos como metodologia didática, é a atuação no aspecto de desenvolvimento de habilidades como coordenação, força, concentração, destreza, rapidez, além do trabalho em equipe, compartilhando ocupações e o exercício de responsabilidade. As atividades lúdicas ajudam no progresso da educação psicomotora e consequentemente, no processo escolar. A utilização de atividades com materiais recicláveis como meio de ensino e aprendizagem por intermédio de atividades de química, matemática e física, busca estimular estas alunas a seguirem a área de engenharia e ciências exata. A criação dos jogos lúdicos e interativos foi realizada pelos discentes da Universidade Federal do Pará e integrantes do Programa de Extensão Laboratório de Engenhocas, como exposto na Figura 3.

Figura 3: Oficinas para a construção de jogos interativos com uso de materiais de baixo custo.

Com o propósito de promover a participação das alunas em competições científicas, o projeto realizou a Feira Cientifica na escola Eneida de Moraes, cujo tema ''Tecnologia: ciência, vida e aprendizado'', onde cada aluna apresentou um projeto que envolvesse as disciplinas de física, química e matemática, buscando conhecimentos interdisciplinares além dos que são vistos dentro da sala de aula, propiciando condições de aprendizagem, onde as mesmas assimilaram, acomodaram e ampliaram os seus conceitos das disciplinas, paralelamente, incorporaram o novo conhecimento adquirido, com influência direta em áreas da engenharia e da ciência aplicada (Figura 4).

Figura 4: Realização da Feira ''Tecnologia: ciência, vida e aprendizado'' na E.E.F.M.Eneida de Moraes.

Em seguida, os discentes do Programa de Extensão Laboratório de Engenhocas elaboraram outra dinâmica de introdução à Robótica, desta vez utilizando Kits LEGO MINDSTORMS. Primeiramente iniciaram uma palestra sobre o Kit educacional, dando à oportunidade as alunas de Ensino Médio a estudarem e terem contato com conceitos básicos da robótica. Logo após, foi explicado a programação, o funcionamento, as peças contidas em cada kit e suas relativas funções, bem como o aplicativo no dispositivo Android, o qual facilita o manuseio do robô. Foram expostos também os variados tipos de projetos os quais tornariam o método de ensino mais interativo e dinâmico, facilitando à aprendizagem e despertando habilidades distintas para montagem de cada robô LEGO (Figura 5).

Figura 5: Dinâmica de Introdução à Robótica com os Kits LEGO MINDSTORMS

4 Resultados e Discussões

Diante da situação exposta, no que diz respeito à busca pela isonomia no mercado de trabalho na área da engenhara e ciências exatas, foi criado no estado do Pará, especificamente no município de Ananindeua, um polo da Universidade Federal do Pará ofertando os cursos de Bacharelado em Ciência e Tecnologia, Engenharia de Materiais e Tecnologia em Geoprocessamento. Visto as necessidades em decorrência da expansão socioeconômica do município de Ananindeua, a Universidade Federal do Pará gerou este polo com a meta de promover a qualificação da mão de obra, especialmente a feminina, para atuação no mercado local.

Isto posto, oficinas de Introdução à robótica, construção de jogos interativos e experimentos de física, química e matemática, foram desenvolvidos na Escola Estadual de Ensino Médio Eneida de Morais no município de Ananindeua para alunas de ensino médio, com o intuito de aproximá-las das disciplinas de exatas e futuramente dos cursos. De acordo com o cronograma previsto, as alunas no final de cada oficina apresentaram um projeto, baseados na didática utilizada no decorrer do treinamento e em pesquisa nos meios digitais e livros, os alunos também tiveram tutoria das professoras presentes, assim como, dos discentes da UFPA envolvidos. Os projetos apresentados pelas alunas foram satisfatórios à medida que foi confirmada a absorção da ideia utilizada no decorrer das oficinas e, principalmente, por haver a percepção de compromisso e interesse das mesmas em aprenderem física, matemática e química de forma a usarem uma metodologia inovadora.

As oficinas foram realizadas no período de julho de 2014 a dezembro de 2014, neste período, as alunas do terceiro ano do ensino médio da Escola Estadual do município de Ananindeua, estavam pleiteando a aprovação em algum processo seletivo, para assim, ingressarem na Universidade. Diante de todo incentivo por parte do programa ''Estimulando a formação de futuras engenheiras'' do Laboratório de Engenhocas, algumas alunas obtiveram aprovações em universidades nos cursos de engenharia e ciências exatas. Entre elas, a aluna Ana Caroline a Silva Reis foi aprovada na Universidade Federal do Pará (UFPA) no curso de Bacharelado em Ciência e Tecnologia e na Faculdade Metropolitana da Amazônia (FAMAZ) no curso de Engenharia Civil.

É perceptível a mudança nos alunos no que se refere a sua familiarização com as disciplinas de física, química e matemática, bem como sua melhoria no desempenho nas avaliações semestrais na Escola e o fomento a ingressar nas áreas de exatas e engenharia, observando-se ainda, o compromisso dos docentes da Escola, em expandir essa metodologia para suas aulas.

5 Considerações Finais

As atividades desenvolvidas no interior do laboratório multidisciplinar da E.E.F.M. Eneida de Moraes, por intermédio da parceria estabelecida com o Laboratório de Engenhocas, demonstram a importância de como as estratégias de aprendizagem ativa com uso de uma metodologia inovadora pode tornar eficaz, atrativo e evidente o aprendizado de matérias associadas como complexas.

Estas estratégias facilitam a compreensão das alunas, bem como moldam sua formação acadêmica para o ingresso em uma universidade, além de proporcionar uma interação maior entre elas e a universidade, por parte dos discentes e docentes da Universidade Federal do Pará e integrantes do Programa de Extensão Laboratório de Engenhocas.

A metodologia aplicada por parte do Programa de Extensão Laboratório de Engenhocas teve grande efeito com as alunas da E. E. F. M. Eneida de Moraes, pois contribuiu na facilidade de matérias consideradas complexas, como também aproximou-as da engenharia e cursos de exata para a futura decisão de profissão.

É esperado que este projeto do Programa de Extensão Laboratório de Engenhocas possa ser um atrativo para as alunas optarem a cursar alguma graduação em engenharia ou ciências exatas, haja vista que nele desenvolvem as principais características de um engenheiro. Portanto, foi feita uma parceria entre o Laboratório de Engenhocas e a Escola de Ensino Médio de Ananindeua no "Estimulando a Formação de Futuras Engenheiras", o qual se tornou o principal meio de identificar talentos. Acredita-se que com o andamento do projeto, possa conseguir tornar o ensino nas escolas mais didáticas contribuindo para o aprendizado das alunas e atraindo-as para as universidades.

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